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ABSTRACT

This teacher's guide contains 11 units of instruction for a course on computer electronics and computer-assisted drafting (CAD) using a personal computer (PC). The course covers the following topics: introduction to electronic drafting with CAD; CAD system and software; basic electronic theory; component identification; basic integrated circuit families and packages; logic, schematic, and other diagrams; electronic packaging design; PC board design; PC board layout; PC board fabrication; and production packages. Each of the instructional units, which are keyed to similar student units of study, includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets and written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheets, assignment sheets, student supplements, and job sheets. All of the unit components focus on measurable and observable learning outcomes; they are designed for use in more than one lesson or class period of instruction. In addition to the units of study, the teacher's edition contains instruction for using the publication, a competency profile, an instructional and task analysis, a list of related academic and workplace skills, a tools, equipment and materials list, and a list of 34 references. (KC)

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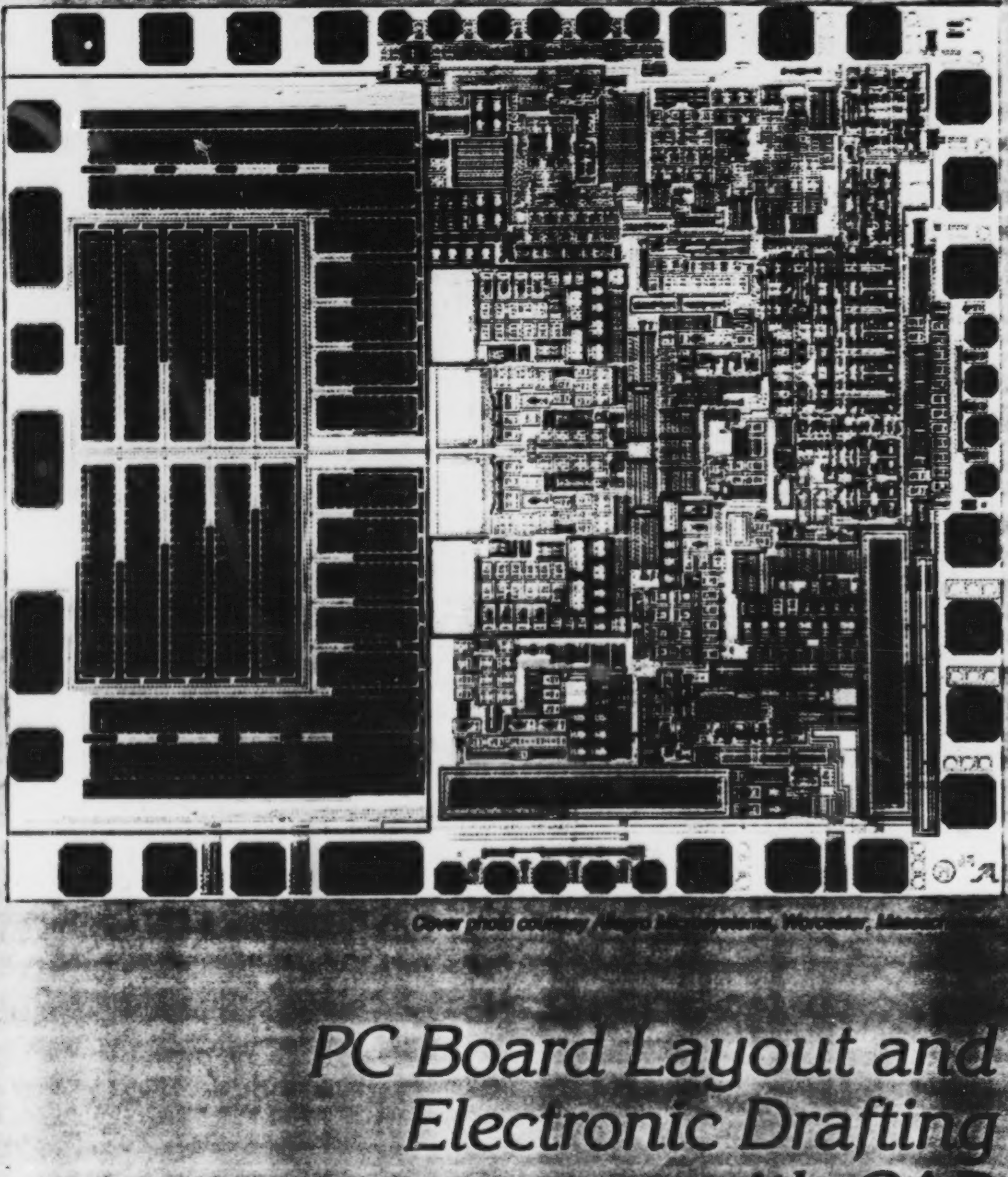

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PC Board Layout and Electronic Drafting with CAD

Teacher Edition

MAVCC

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PC Board Layout
and
Electronic Drafting With CAD

Teacher Edition

Table of Contents

Foreword v
Acknowledgements vii
Use of introductory materials ix
Use of this publication xi
Academic and workplace skills classification and definitions xv
Competency profile xvii
Instructional/task analysis xxi
Related academic and workplace skills list xxxi
Tools, equipment, and materials list xxxv
References xxxvii

Unit 1: Introduction to Electronic Drafting With CAD 1

Unit 2: CAD Systems and Software 25

Unit 3: Basic Electronic Theory 37

Unit 4: Component Identification 55

Unit 5: Basic IC Families and Packages 87

Unit 6: Logic, Schematic, and Other Diagrams 115

Unit 7: Electronic Packaging Design 147

Unit 8: PC Board Design 163

Unit 9: PC Board Layout 185

Unit 10: PC Board Fabrication 205

Unit 11: Production Packages 219

Foreword

PC Board Layout and Electronic Drafting With CAD is much more than a revision of MAVCC's original *Electronic Drafting* text. The major improvement is that schematics and other diagrams in the text are mostly taken from data books and other publications by major manufacturers of electronic equipment. The articulate drawings not only enhance the text, they present real products that students will work with later in their drafting careers.

As with other revisions in the MAVCC drafting series, we demonstrate applications and stress advantages of using a CAD workstation. However, the text is also designed to give the beginning student enough board time to make an easy transistion to CAD. At practical points in the text, we challenge students to make the transition to CAD with a **CAD Alert** which is demonstrated below.

CAD Alert: You can complete this assignment sheet much faster with a CAD system. Parts of the schematic can be drawn and saved, and modified as required at a later date without the need of redrawing.

Units of the text that deal with pc board development have been changed to reflect modern trends in miniaturization and sophistication. Old processes have been updated to facilitate new products, and new concepts in surface mounted technology are presented and demonstrated.

As you use these instructional materials, we hope you find they contribute to the quality of your drafting program. Every effort has been made to make these readable, and by all means useable. As an instructor, you will need to develop instructional strategies for localizing, individualizing, and supplementing the text. Most of all, you will need to motivate the students who will join you in using these materials.

As always, MAVCC appreciates hearing from people who use our publications. Please write or call MAVCC and share your opinions about *PC Board Layout and Electronic Drafting With CAD*. Tell us what you like or don't like. Tell us what is needed to make the text better. We want to hear from you.

Sylvia Clark, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Jim Steward
Executive Director
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Charles Carbonneau	Engineering Department Head, Lake Area Technical Institute, Watertown, South Dakota

A special thank you goes out to suppliers and manufacturers who have generously supported our efforts with permission to reprint significant schematics and other drawings that greatly enhance many pages of this text. Our gratitude also goes to Allegro Microsystems, Inc., of Worcester, Massachusetts, for permission to use the excellent working drawing on the cover of *PC Board Layout and Electronic Drafting With CAD.*

To the Oklahoma Department of Vocational-Technical Education, we extend a special thank you to wordprocessing personnel for superior typing and phototypesetting services, to members of the art department for careful paste-up work, and to the ODVTE Print Shop for excellent printing.

Use of Introductory Materials

Introductory materials are included in the teacher guide only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, foreword, and acknowledgements page, information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/ learning process.

2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.

3. **Instructional/task analysis**—Provides a quick review of contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.

4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills being reinforced. Skill areas reflected by skill groups, sub skills, and descriptions have been identified using *Workplace Basics: The Skills Employers Want*, developed by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment sheets and/or job sheets; assists administrator/teacher in determining program costs.

6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.

A glossary of terms may also be provided in the introductory materials depending on subject matter and committee recommendations.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

PC Board Layout and Electronic Pipe Drafting With CAD contains eleven units of instruction. Each instructional unit in a teacher guide includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, assignment sheets, student supplements, and job sheets.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Objective sheet (Color code: White)

Each unit of instruction is based on performance objectives which state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives which state the expected performance of each student after completion of the unit of instruction, and specific objectives which state what the student must do to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested activities (Color code: Pink)

This component is included only in the teacher guide. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teacher suggestions, and skill areas have been noted in bold. (A table of academic and workplace skills with accompanying definitions has been provided on page xv.) The teacher should read the suggested activities before teaching the units and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Instructions for evaluating student performance on the job sheets are also included in the suggested-activities section. Teachers should select and discuss with students the rating scale that will be used.

Assignment and written test answers (Color code: Pink)

Assignment-sheet answers and written-test answers are designed to assist the teacher in evaluation of student performances.

Written test (Color code: Yellow)

This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction. The test appears in the teacher guide only, but duplication is permitted for student use. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

Unit evaluation form (Color code: White)

This sheet provides teachers with a record of each students performance on a unit of instruction. It includes space for assignment sheet ratings, job sheet ratings, written test scores, and teacher comments. The unit evaluation form is included in the teacher guide only, but may be duplicated.

Use of This Publication

Teacher supplements (Color code: White)

This component is included only in the teacher guide. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters (Color code: White)

Transparencies are included in the teacher guide only and are used to direct the students' attention to the topic of discussion. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Information sheet (Color code: Green)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements (Color code: White)

Student supplements are included in the student manual. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment sheets or job sheets.

Assignment sheets (Color code: Tan)

Assignment sheets provide students with pencil and paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets (Color code: Blue)

The job sheets provide criteria to objectively evaluate student performance, a list of required equipment and materials, and a step-by-step procedure for performing a psychomotor skill. The teacher should discuss the equipment and materials available in the classroom and/or laboratory and demonstrate the procedure prior to having students practice procedure. When a student is ready to be evaluated, the teacher should follow instructions for evaluating student performance which may be found in the teacher guide.

Job sheets are an important segment of each unit. Job sheets provide potential employers with a picture of the skills being taught during training and the performances that might reasonably be expected from an individual who has had this training.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder or folder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some teachers prefer to store the material by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student manuals contain objective sheets, information sheets, student supplements, assignment sheets, and job sheets. Students should be allowed to take their materials home at the end of the course.

Academic and Workplace Skills
(Classifications and Definitions)

Skill Groups	Sub Skills	Definitions
Learning Skills	Learning to learn	Developing ability to apply knowledge to other situations; knowing how to learn.
Foundation Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Math	Applying computation skills such as reasoning, estimation, and problem solving as they are actually used on the job.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
Communication Skills	Listening	Listening for content, conversation, long-term contexts, emotional meaning, and directions.
	Oral communication	Communicating a thought, idea, or fact in spoken form in a clear, concise manner.
Adaptability Skills	Creative thinking	Using imagination to create something new—i.e. an idea, invention, work of art.
	Problem solving (critical thinking)	Recognizing and defining problems, inventing, and implementing solutions, and tracking and evaluating results.
Personal Management Skills	Self-esteem	Developing self-confidence and creating a positive self-image.
	Motivation/goal setting	Setting and meeting defined goals and objectives.
	Personal and career development	Emphasizing self-direction by establishing and implementing a plan.
Group Effectiveness Skills	Interpersonal relations	Developing ability to maintain positive relations with others.
	Negotiation	Resolving conflict between two or more individuals.
	Teamwork	Working together in a group to reach a common goal.
Influence Skills	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Leadership	Directing/influencing group in performance of a specific task; accepting responsibility for others.

PC Board Layout
and
Electronic Drafting With CAD

Competency Profile

Name: ______________________________

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focuses on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Option A

Rating scale:
4 - Skilled - Can perform job with no additional training.
3 - Moderately Skilled - Has performed job during training program; limited additional training may be required.
2 - Limited Skill - Has performed job during training program; additional training is required to develop skill.
1 - Unskilled - Is familiar with process, but is unable to perform job.
0 - No Exposure - No information or practice provided during training program, complete training required.
NA - Non-applicable.

Option B

Yes - Can perform with no additional training
No - Is unable to perform satisfactorily

Unit 1 Introduction to Electronic Drafting

______1. Draw a finished schematic from an engineer's sketch using templates and a CAD system.
______2. Copy a schematic using manual techniques with electronic templates or on a CAD system.
______3. Redraw a CAD-generated schematic.
______4. Sketch the pin configurations and gate locations of selected chips.
______5. Sketch the mechanical configurations of selected electronic components.
______6. ______________________________

______Written Test Score

Unit 2 CAD Systems and Software

______1. Locate and identify parts of a CAD system.
______2. Locate, print, and sketch items from symbol libraries.
______3. ______________________________

______Written Test Score

Competency Profile (Cont.)

Unit 3: Basic Electronic Theory

______1. Solve problems using Ohm's law.
______2. Determine the resistance of series and parallel circuits.
______3. ________________________________

______Written Test Score

Unit 4: Component Identification

______1. Use the color code to determine resistor values.
______2. Draw selected component symbols.
______3. Draw a schematic diagram.
______4. Select components and hardware from reference manuals.
______5. ________________________________

______Written Test Score

Unit 5: Basic IC Families and Packages

______1. Draw schematic symbols for analog and digital ICs.
______2. Number pins on IC packages.
______3. Sketch analog symbols and IC packages.
______4. Sketch digital symbols and IC packages.
______5. ________________________________

______Written Test Score

Unit 6: Logic, Schematic, and Other Diagrams

______1. Redraw an existing schematic.
______2. Sketch a schematic on grid paper.
______3. Draw a schematic.
______4. Draw a harness layout.
______5. Draw a block diagram.
______6. ________________________________

______Written Test Score

Unit 7: Electronic Packaging Design

______1. Use datum dimensioning to make a board outline drawing.
______2. Draw component outline "dolls."
______3. Draw chassis and package types from manufacturers' catalogs.
______4. Design and draw an electronic package.
______5. ________________________________

______Written Test Score

Competency Profile (Cont.)

Unit 8: PC Board Design

______1. Use the designated method to determine the total usable area of selected PC boards.
______2. Use the estimated method to determine minimum PC board size.
______3. Determine component density of a PC Board.
______4. Design a printed circuit board.
______5. ______________________________

______Written Test Score

Unit 9: PC Board Layout

______1. Print available symbols from a CAD system pc board library and create new symbols for common components.
______2. Construct a layout for a pc board and plot the finished work.
______3. ______________________________

______Written Test Score

Unit 10: PC Board Fabrication

______1. Prepare artwork for pc board fabrication.
______2. Evaluate a commercial pc board fabrication process.
______3. ______________________________

______Written Test Score

Unit 11: Production Package

______1. Complete an assembly drawing.
______2. Complete a bill of materials for an assembly drawing.
______3. Complete an assembly drawing using an intermediary and photocopy method.
______4. ______________________________

______Written Test Score

COMMENTS: ______________________________

____

____

Evaluator: ____________________ Date: ____________________

*** Permission to duplicate this profile is granted.**

PC Board Layout and Electronic Drafting With CAD

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Introduction to Electronic Drafting With CAD

1. Terms and definitions
2. CAD software and its applications
3. Career outlook for electronic drafters
4. Planning an electronic drafting career
5. Guidelines for becoming a good CAD operator
6. Precision measuring equipment used in electronic drafting
7. Special templates and their uses in electronic drafting
8. Tools used by electronic drafters
9. Graphic aids and their uses in electronic drafting
10. References and their importance in electronic drafting
11. Elements of electronic drafting and their characteristics
12. Draw a finished schematic from an engineer's sketch using templates and a CAD system. (Assignment Sheet 1)
13. Copy a schematic using manual techniques with electronic templates or on a CAD system. (Assignment Sheet 2)
14. Redraw and label a CAD-generated schematic. (Assignment Sheet 3)
15. Sketch the pin configurations and gate locations of selected chips. (Assignment Sheet 4)
16. Sketch the mechanical configurations of selected electronic components. (Assignment Sheet 5)

Unit 2: CAD Systems and Software

1. Terms and definitions
2. General CAD commands for PCB layout and their definitions
3. Specific CAD commands for PCB layout and their definitions

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 2: CAD Systems and Software (Cont.)

4. Major CAD applications for electronic drafting
5. CAD system input data required for PCB layout
6. Types of output generated by a CAD system
7. Types of hardware used in a CAD workstation
8. Operator input devices and their uses
9. Steps in CAD-developed documentation
10. Available turnkey CAD systems

11. Locate and identify parts of a CAD system. (Assignment Sheet 1)
12. Locate, print, and sketch items from symbol libraries. (Assignment Sheet 2)

Unit 3: Basic Electronic Theory

1. Terms and definitions
2. Problems related to elements of Ohm's law
3. Guidelines for expressing and using powers of ten
4. Applications of descrete devices and ICs
5. IC families and their characteristics
6. IC circuit families and abbreviations for their logic configurations
7. Typical digital and analog applications
8. Basic types of circuits and their characteristics
9. Formulas for finding resistance in series and parallel circuits

10. Solve problems using Ohm's law. (Assignment Sheet 1)
11. Determine the resistance of series and parallel circuits. (Assignment Sheet 2)

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 4: Component Identification

1. Terms and definitions
2. Resistor symbols
3. Capacitor symbols
4. Inductor and transformer symbols
5. Diode symbols
6. Transistor symbols
7. IC symbols
8. Switches and their symbols
9. Connector symbols
10. Component abbreviations and their meanings
11. Reference designation class letters and their definitions
12. Steps in reading reference designations
13. How to determine resistor values
14. Packaging techniques for resistors and potentiometers
15. Packaging techniques for capacitors
16. Packaging techniques for inductors and transformers
17. Packaging techniques for diodes
18. Packaging techniques for transistors
19. Packaging techniques for integrated circuits

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 4: Component Identification (Cont.)

20. Packaging techniques for switches
21. Mounting hardware and its applications
22. Connectors and terminals and their applications

23. Use the color code to determine resistor values. (Assignment Sheet 1)
24. Draw selected component symbols. (Assignment Sheet 2)
25. Draw a schematic diagram. (Assignment Sheet 3)
26. Select components and hardware from reference manuals. (Assignment Sheet 4)

Unit 5: Basic IC Families and Packages

1. Terms and definitions
2. Analog devices and their characteristics
3. Package schematic diagrams for analog devices
4. Analog devices and their requirements
5. Information found in analog reference material
6. Digital gate and device symbols
7. Package diagrams and schematic diagrams for digital devices
8. Digital devices and their designs
9. Gate package equivalent functions
10. Pin locations for both analog and digital ICs
11. Information found in digital reference materials

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know	**Application: What the Student Should Be Able to Do**
Unit 5: Basic IC Families and Packages (Cont.)	
12. IC technology and its applications	15. Draw schematic symbols for analog and digital ICs. (Assignment Sheet 1)
13. Surface mounted technology	
14. IC package types and their uses	16. Number pins on IC packages. (Assignment Sheet 2)
	17. Sketch analog symbols and IC packages. (Assignment Sheet 3)
	18. Sketch digital symbols and IC packages. (Assignment Sheet 4)
Unit 6: Logic, Schematic, and Other Diagrams	
1. Terms and definitions	
2. Block diagrams and their applications	
3. Guidelines for drawing block diagrams	
4. Logic diagrams and their applications	
5. Guidelines for drawing logic diagrams	
6. Logic diagram abbreviations and their meanings	
7. Types of schematic drawings and their applications	
8. What schematics do	
9. Guidelines for drawing schematics	
10. Guidelines for applying schematic line conventions	
11. Stage designation for circuits on schematics	

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 6: Logic, Schematic, and Other Diagrams

12. Special symbols and their meanings
13. Purposes of notes on schematics
14. Elements in a wire list
15. Types of cables and cable connectors
16. Elements in cable assembly drawings
17. Harness terms and their definitions
18. Components of a harness
19. Elements in harness assembly drawings
20. Termination abbreviations

21. Redraw an existing schematic. (Assignment Sheet 1)
22. Sketch a schematic on grid paper. (Assignment Sheet 2)
23. Draw a schematic. (Assignment Sheet 3)
24. Draw a harness layout. (Assignment Sheet 4)
25. Draw a block diagram. (Assignment Sheet 5)

Unit 7: Electronic Packaging Design

1. Terms and definitions
2. Elements of electronic package design and their considerations
3. Types of commercial chassis configurations
4. Dimensioning techniques for electronic packaging
5. Guidelines for package layout

6. Use datum dimensioning to make a board outline drawing. (Assignment Sheet 1)
7. Draw component outline "dolls." (Assignment Sheet 2)
8. Draw chassis and package types from manufacturers' catalogs. (Assignment Sheet 3)
9. Design and draw an electronic package. (Assignment Sheet 4)

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 8: PC Board Design

1. Terms and definitions
2. Scaling factors and their use in PC board design
3. Designated and estimated methods for determining usable space on PC boards
4. Considerations for determining PC board sizes
5. Tooling holes in PC board design
6. Elements of component drawings and their applications
7. Methods for making board outline drawings
8. Graphical representations and their applications in PC board design
9. Guidelines for designing a PC board
10. Use the designated method to determine the total usable area of selected PC boards. (Assignment Sheet 1)
11. Use the estimated method to determine minimum PC board size. (Assignment Sheet 2)
12. Determine component density of a PC board. (Assignment Sheet 3)
13. Draw a printed circuit board. (Assignment Sheet 4)

Unit 9: PC Board Layout

1. Terms and definitions
2. PC board layout requirements
3. Component information required for pc board layout
4. Hardware and software requirements for pc board layout
5. Other considerations for CAD pc board layout
6. Grid applications and spacing
7. Common layout scales

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do

Unit 9: PC Board Layout

Related Information: What the Student Should Know

8. Selecting trace widths
9. Guidelines for spacing traces
10. Guidelines for trace layout
11. Type of terminal holes an their functions
12. Determining minimum size
13. Grounding methods and their applications
14. Busing techniques
15. Shielding considerations
16. Shielding techniques
17. Peripheral orientation
18. Laying out a pc board on a CAD system

Application: What the Student Should Be Able to Do

19. Print available symbols from a CAD pc board library and create new symbols for common components. (Assignment Sheet 1)
20. Construct a layout for a pc board and plot the finished artwork. (Assignment Sheet 2)

Unit 10: PC Board Fabrication

Related Information: What the Student Should Know

1. Terms and definitions
2. Preliminary steps for pc board fabrication
3. Preparing artwork
4. The pc board photographic process
5. Steps in pc board etching
6. Steps in pc board final fabrication

Application: What the Student Should Be Able to Do

7. Prepare artwork for pc board fabrication . (Assignment Sheet 1)
8. Evaluate a commercial pc board fabrication process. (Assignment Sheet 2)

Instructional/Task Analysis (Cont.)

Related Information: What the Student Should Know

Unit 11: Production Packages

1. Terms and definitions
2. Production package components
3. Guidelines for making an assembly drawing
4. The CAD system method for preparing assembly drawings
5. The halftone method for preparing assembly drawings
6. The outline artwork method for preparing assembly drawings
7. The component layout method for preparing assembly drawings
8. The component/master copy method for preparing assembly drawings
9. The overlay method for preparing assembly drawings
10. The photodrawing method for preparing assembly drawings
11. Notes for assembly drawings
12. Information on a bill of materials
13. Screw heads used for mounting hardware
14. Machine screw drive configurations used for mounting hardware
15. Nuts and fasteners used for mounting hardware
16. Types of washers used for mounting hardware
17. Other devices used for mounting hardware

Application: What the Student Should Be Able to Do

18. Complete an assembly drawing. (Assignment Sheet 1)
19. Complete a bill of materials for an assembly drawing. (Assignment Sheet 2)
20. Complete an assembly drawing using an intermediary and photocopy method. (Assignment Sheet 3)

Related Academic and Workplace Skills
For *PC Board Layout and Electronic Drafting With CAD*

Task	Skill Group	Sub Skill	Description
Unit 1: Introduction to Electronic Drafting With CAD			
Draw a finished schematic from an engineer's sketch using templates and a CAD system. (A.S. 1)	Adaptability Skills	Problem solving	Recognizes elements of a task and implements a solution
Copy a schematic using manual techniques with electronic templates or on a CAD system. (A.S. 2)	Adaptability Skills	Problem solving	Recognizes elements of a task and implements a solution
Redraw and label a CAD-generated schematic. (A.S. 3)	Foundation Skills	Science	Applies knowledge learned through study to complete a task
Sketch the pin configurations and gate locations of selected chips. (A.S. 4)	Foundation Skills	Science	Applies knowledge learned through study to complete a task
Sketch the mechanical configurations of selected electronic components. (A.S. 5)	Foundation Skills	Science	Applies knowledge learned through study to complete a task
Unit 2: CAD Systems and Software			
Locate and identify parts of a CAD system. (A.S. 1)	Foundation Skills	Science	Applies knowledge learned through study to complete a task
Locate, print, and sketch items from symbol libraries. (A.S. 2)	Foundation Skills	Science	Applies acquired knowledge of a system to a task
Unit 3: Basic Electronic Theory			
Solves problems using Ohm's Law. (A.S. 1)	Foundation Skills	Math	Applies computation skills to solve a problem
Determine the resistance of series and parallel circuits. (A.S. 2)	Foundation Skills	Math	Applies computation skills to solve a problem
Unit 4: Component Identification			
Use the color code to determine resistor values. (A.S. 1)	Adaptability Skills	Problem solving	Recalls color/math relationships to solve problems
Draw selected component symbols. (A.S. 2)	Foundation Skills	Science	Applies drawing skills to complete a task
Draw a schematic diagram. (A.S. 3)	Foundation Skills	Science	Applies drawing skills to complete a task
Select components and hardware from reference manuals. (A.S. 4)	Foundation Skills	Reading	Comprehends and follows written instructions

Academic and Workplace Skills (Cont.)

Task	Skill Group	Sub Skill	Description
Unit 5: Basic IC Families and Packages			
Draw schematic symbols for analog and digital ICs. (A.S. 1)	Adaptability Skills	Problem solving	Adapts drawing skills to design a product
Number pins on IC packages. (A.S. 2)	Foundation Skills	Math	Applies industrial conventions to a numbering problem
Sketch analog symbols and IC packages. (A.S. 3)	Foundation Skills	Science	Applies sketching talent to reproduce technical likenesses
Sketch digital symbols and IC packages. (A.S. 4)	Foundation Skills	Science	Applies sketching talent to reproduce technical likenesses
Unit 6: Logic, Schematic, and Other Diagrams			
Redraw and existing schematic (A.S. 1)	Foundation Skills	Science	Applies drawing skills to reproduce a technical drawing
Sketch a schematic on grid paper. (A.S. 2)	Foundation Skills	Science	Applies sketching talent to reproduce a technical drawing
Draw a schematic. (A.S. 3)	Foundation Skills	Science	Applies drawing skills to produce a working drawing
Draw a harness layout. (A.S. 4)	Foundation Skills	Science	Applies drawing skills to complete a technical drawing
Draw a block diagram. (A.S. 5)	Foundation Skills	Science	Applies drawing skills to complete a technical drawing
Unit 7: Electronic Packaging Design			
Use datum dimensioning to make a board outline drawing. (A.S. 1)	Foundation Skills	Science	Applies drawing skills to complete a technical drawing
Draw component outline "dolls." (A.S. 2)	Foundation Skills	Science	Applies drawing skills to complete a technical drawing
Draw chassis and package types from manufacturers' catalogs. (A.S. 3)	Foundation Skills	Science	Applies drawing skills to reproduce a technical drawing
Design and draw an electronic package. (A.S. 4)	Adaptability Skills	Creative thinking	Applies personal abilities to a complex task
Unit 8: PC Board Design			
Use the designated method to determine the usable area of a selected PC board. (A.S. 1)	Foundation Skills	Math	Applies mathematical formulas to a process
Use the estimated method to determine	Foundation Skills	Math	Applies mathematical formulas to a process

Academic and Workplace Skills (Cont.)

Task	Skill Group	Sub Skill	Description
Unit 8: (Cont.)			
Determine component density of a PC board. (A.S. 3)	Foundation Skills	Math	Applies mathematical formulas to a process
Draw a printed circuit board. (A.S. 4)	Foundation Skills	Science	Applies drawing skills to draw a technical drawing
Unit 9: PC Board Layout			
Print available symbols from a pc board library and create new symbols for common components. (A.S. 1)	Foundation Skills	Science	Applies computer skills to reproduce data
Construct a layout for a pc board and plot the finished artwork. (A.S. 2)	Foundation Skills	Math	Applies drawing skills to construct a project
Unit 10: PC Board Fabrication			
Prepare artwork for pc board fabrication. (A.S. 1)	Foundation Skills	Math	Applies computer skills to prepare artwork
Evaluate a commercial pc board fabrication process. (A.S. 2)	Learning Skills	Learning to learn	Uses acquired knowledge to evaluate a process
Unit 11: Production Package			
Complete an assembly drawing. (A.S. 1)	Foundation Skills	Math	Applies drawing skills to complete a project
Complete a bill of materials for an assembly drawing. (A.S. 2)	Foundation Skills	Science	Transposes technical information to a form
Complete an assembly drawing using an intermediary and photocopy method. (A.S. 3)	Foundation Skills	Science	Combines two methods to produce a drawing

PC Board Layout
and
Electronic Drafting With CAD

Tools, Materials, and Equipment List

Hardware

Computer with monitor and keyboard
Mouse or graphics tablet with mouse
Plotter
Printer

Software

DOS, version 5.0 or later
PC board specific software such as HIWIRE or PADS

Basic Drafting Instruments

Compass
Drafting pencils
Eraser
Scales
T-square or drafting machine
Triangles

Darkroom facilities and equipment

Darkroom with safelight
Developing frame
Drying line with clamps or clothes pins
Etchant with appropriate Material Safety Data Sheet (MSDS)
Etcher tray
Kodak Ortho Type II film or equivalent
Presensitized pc boards
Safety goggles, apron, and gloves
Wash basin and running water facilities

PC Board Layout and Electronic Drafting With CAD

References

ANSI/IEEE 91-1984, Graphic Symbols for Logic Functions. New York: American national Standards Institute, 1984.

ANSI/IEEE 100-1988, Dictionary of Electrical and Electronics Terms. New York: American national Standards Institute, 1988.

ANSI/IEEE 200-1975 (R1989), Reference Designations for Electrical and Electronic Parts and Equipment. New York: American National Standards Institute, 1989.

ANSI/IEEE 260-1978, Letter Symbols for SI Units and Certain Other Units of Measurement. New York: American National Standards Institute, 1992.

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Baer, Charles J. and John R. Ottaway. *Electrical and Electronic Drawing*, 5th ed. New York: McGraw-Hill, Inc., 1986.

Boylestad, Robert, and Louis Nashelsky. *Electronic Devices and Circuit Theory*, 3rd ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1982.

Byers, T. J. *Printed Circuit Board Design with Computers.* NY: McGraw-Hill, 1991.

CMOS Logic Data, DL 131 REV3. Phoenix, AZ: Motorola, Inc., 1991.

Coombs, Clyde F., Jr. *Printed Circuits Handbook*, 3rd ed. NY: McGraw-Hill, 1988.

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Coombs, Clyde F. *Printed Circuits, Vol. 2: Fabrication.* NY: McGraw-Hill, 1990.

Coombs, Clyde F. *Printed Circuits, Vol. 3: Soldering.* NY: McGraw-Hill, 1990.

Coombs, Clyde F. *Printed Circuits, Vol. 4: Assembly & Testing.* NY: McGraw-Hill, 1991.

Coombs, Clyde F. *Printed Circuits, Vol. 5: Multilayer & Flexible Circuits.* NY: McGraw-Hill, 1991.

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Linear & Telecom ICs FOR ANALOG SIGNAL PROCESSING APPLICATIONS 1993-94. Melbourne, FL: Harris Corporation, 1993.

McClain, Gerald R. and Neal A. Wilson. *Electronic Drafting.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1983.

Newark Electronics, Catalog 113. Chicago, IL: Neward Electronics, 1994.

Operational Amplifiers Databook. Operational Amplifiers. Buffers. Voltage Comparators. Santa Clara, CA: National Semiconductor Corporation, 1992.

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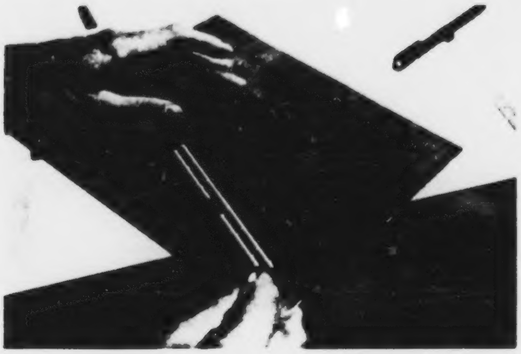


Introduction to Electronic Drafting With CAD
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to use a CAD system to draw a finished schematic from an engineering drawing, use manual and electronic techniques to copy a schematic, redraw and label a CAD-generated schematic, use reference material to sketch pin configurations and gate locations in chips, and sketch various components. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electronic drafting with CAD with their correct definitions.
2. Complete statements about CAD software and its applications.
3. Select true statements about the career outlook for electronic drafters.
4. Select true statements about guidelines for planning and electronic drafting career.
5. Complete statements about guidelines for becoming a good CAD operator.
6. Identify precision measuring equipment used in electronic drafting.
7. Complete statements about special templates and their uses in electronic drafting.
8. Identify other tools used by electronic drafters.
9. Complete statements about graphic aids and their uses in electronic drafting.

Objective Sheet

10. Select true statements about references and their importance in electronic drafting.

11. Match elements of electronic drafting with their characteristics.

12. Draw a finished schematic from an engineer's sketch using templates and a CAD system. (Assignment Sheet 1)

13. Copy a schematic using manual techniques with electronic templates or on a CAD system. (Assignment Sheet 2)

14. Redraw and label a CAD-generated schematic. (Assignment Sheet 3)

15. Sketch the pin configurations and gate locations of selected chips. (Assignment Sheet 4)

16. Sketch the mechanical configurations of selected electronic components. (Assignment Sheet 5)

Introduction to Electronic Drafting With CAD
Unit 1

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. There are no transparency masters with this unit, but make your own if you see a need for visual enhancement of any of the objectives.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.
11. Discuss and demonstrate the procedures in the job sheets, and obtain any special tools and materials required.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Take advantage of Objectives 3 and 4 to discuss with students the career possibilities of electronic and printed circuit board drafting. Invite local drafters with electronic drafting experience to talk to the class about jobs, pay, working conditions, and the general advantages of selecting the electronic area of drafting as a career. Skill areas: **Personal management skills, personal and career development.**

2. Appoint or have students from their own groups to evaluate an electronic drawing. Have respective members of the group discuss neatness, linework, and how well the drawing will reproduce. Skill areas: **Group effectiveness skills, teamwork.**

3. Talk with students about electronic drafting reference materials, their contents, and the important of reference materials to all drafting. Have students check and list the reference materials immediately available in the drafting program. Skill areas: **Learning skills, learning to learn.**

Suggested Activities

Resources Used in Developing This Unit

1. *ANSI/IEEE 91-1984, Graphic Symbols for Logic Functions.* New York: American National Standards Institute, 1984.

2. *ANSI/IEEE 100-1988, Dictionary of Electrical and Electronics Terms.* New York: American National Standards Institute, 1988.

3. *ANSI/IEEE 200-1975 (R1989), Reference Designations for Electrical and Electronic Parts and Equipment.* New York: American National Standards Institute, 1989.

4. *ANSI/IEEE 260-1978, Letter Symbols for SI Units and Certain Other Units of Measurement.* New York: American National Standards Institute, 1992.

5. *FAST™ and LS TTL Data.* Phoenix, AZ: Motorola, Inc., 1992.

6. *Integrated and Discrete Semiconductors, AMS-501.* Worcester, MA: Allegro Microsystems, Inc., 1993.

7. *Intelligent Power™ ICs FOR COMMERCIAL, INDUSTRIAL AND AUTOMOTIVE APPLICATIONS.* Melbourne, FL: Harris Corporation, 1992.

8. *Linear & Telecom ICs FOR ANALOG SIGNAL PROCESSING APPLICATIONS 1993-94.* Melbourne, FL: Harris Corporation, 1993.

Suggested Supplement Resources

Linear & Telcom ICs FOR ANALOG SIGNAL PROCESSING APPLICATIONS 1993-94 is an excellent data book published by Harris Semiconductor. For information about this and other data books, write to:

Harris Corporation
Semiconductor Sector
P.O. Box 883
Melbourne, FL 32902

Integrated and Discrete Semiconductors, AMS-501 is a complete semiconductor catalog with impressive application notes and excellent illustration. The catalog is available from Allegro at 508-853-5000 or write:

Allegro MicroSystems, Inc.
115 Northeast Cutoff, Box 15036
Worcester, MA 01615

Suggested Activities

Fast and LS TTL Data is another excellent source for semiconductor information. This data book is published by the Logic Integrated Circuits Division of Motorola. For information, write:

Motorola Literature Distribution
P.O. Box 20912
Phoenix, AZ 85036

Introduction to
Electronic Drafting With CAD
Unit 1

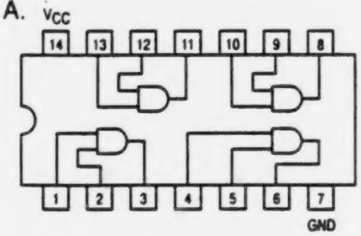
Answers to Assignment Sheet

Assignment Sheets 1, 2, and 3

Evaluate according to criteria written in the respective assignment sheets.

Assignment Sheet 4

A.


VCC
14
13
12
11
10
9
8
1
2
3
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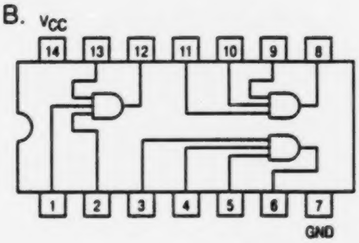
6
7
GND

B.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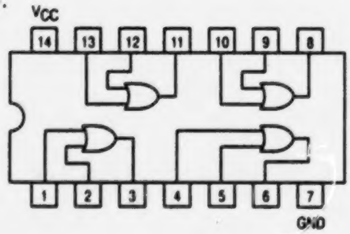
C.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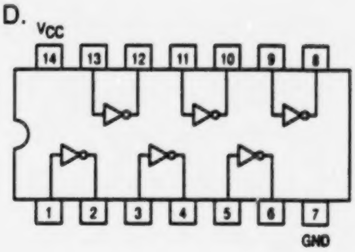
D.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GND

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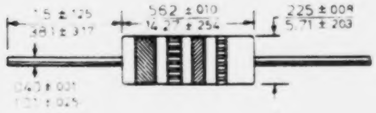
Answers to Assignment Sheets

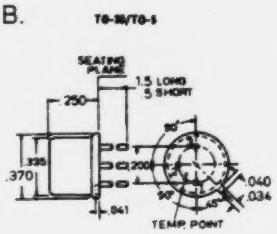
Assignment Sheet 5

Note: Answers may vary depending on resource material.

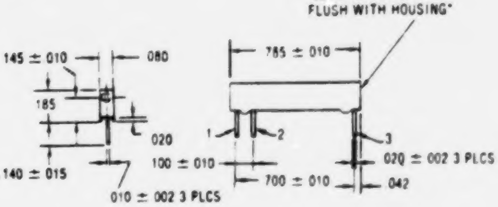
A.


1.5 ± .125
38.1 ± 3.17
.562 ± .010
14.27 ± .254
.225 ± .008
5.71 ± .203
.043 ± .001
1.21 ± .025

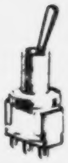
B.


TO-39/TO-5
SEATING PLANE
1.5 LONG
.5 SHORT
.250
.335
.370
.200
.041
90°
90°
45°
.040
.036
TEMP. POINT

C.


064 DIA ADJ SHAFT
FLUSH WITH HOUSING*
145 ± 010
080
785 ± 010
185
020
1
2
3
100 ± 010
020 ± 002 3 PLCS
140 ± 015
700 ± 010
042
010 ± 002 3 PLCS

D.



Introduction to
Electronic Drafting With CAD
Unit 1

Answers to Written Test

1. a. 5
   b. 9
   c. 7
   d. 3
   e. 8
   f. 1
   g. 10
   h. 6
   i. 2
   j. 4

2. a. Drafting
   b. Application-specific
   c. As a print
   d. A bill of materials
   e. Symbols

3. a. Almost all kinds of
   b. Expensive
   c. Decreasing, increasing (must be in this order!)
   d. $25,000.00
   e. Heating and air conditioning
   f. Communications

4. b, d, e

5. a, b

6. a. 1X standard scale
   b. 1000 & 500 Metric scale
   c. Optical comparator
   d. Reticle

7. a. Logic
   b. Layouts
   c. Combination

8. a. Light table
   b. Precision cutting knife
   c. Swivel knife
   d. Tweezers
   e. Brunisher

Answers to Written Test

9. a. Speed
   b. Components
   c. Leroy lettering set
   d. Plotter
   e. Vellum, vellum

10. a, b, c, d

11.

a.	4	d.	6	g.	5
b.	7	e.	1		
c.	2	f.	3		

Introduction to
Electronic Drafting With CAD
Unit 1

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. An itemized list of parts shown with an assembly drawing

______b. A tool for rubbing letters, numbers, and symbols from transfer sheets onto drawings

______c. Drafting specialized for developing schematics, logic diagrams, ladder diagrams, master patterns, marking drawings, and assembly drawings for use in the electronic industry

______d. A magnifier used for closely checking PCB conductor spacing and width, measured in millimeters and inches

______e. An output device used to print a precision copy of a drawing created on a CAD system

______f. A method for correctly aligning multiple layers used to make a single drawing

______g. A nonconductive common base material with a conductive material laminated on one or more sides with a pattern designed to interconnect electronic components

______h. A system of lines, dots, cross hairs, or wires in the focus of the eyepiece of an optical instrument

1. Pin registration system
2. Schematic
3. Optical comparator
4. Template
5. BOM
6. Reticle
7. Electronic drafting
8. Pen plotter
9. Burnisher
10. PCB

Written Test

_______i. A wiring diagram showing all the components of an electronic circuit and how the components are connected, but the diagram does not show true size, shape, or placement

_______j. A thin, flat, plastic tool with openings representing different shapes and sizes of standard symbols; used to expedite drawing

2. Complete statements about CAD software applications. Circle the material that best completes each of the following statements.

   a. General CAD software is used for almost all kinds of (**printing**) (**drafting**), but is not specifically designed for electronic drafting.

   b. (**Application-specific**) (**Customized**) software is software designed for specific applications such as electronic drafting.

   c. A basic element of electronic drafting software is that it allows a CAD drafter to create a schematic or PCB design and reproduce it (**as a photograph**) (**as a print**).

   d. Application-specific software for electronic drafting is used to draw schematics, design PCBs, and automatically generate (**duplicate copies**) (**a bill of materials**).

   e. Another advantageous element of application-specific software for electronics is that is usually contains a library of (**terms**) (**symbols**) which helps expedite the creation of schematics and PCBs.

3. Complete statements about the career outlook for electronic drafters. Circle the material that best completes each of the following statements.

   a. The demand for (**almost all kinds of**) (**electronic**) drafters will increase through the year 2005.

   b. The demand for drafters experienced in CAD will also increase in the next decade because as CAD systems and software become less (**difficult to use**) (**expensive**), CAD drafting continues to expand.

c. Modern components are (**decreasing**) (**increasing**) in size and (**decreasing**) (**increasing**) in complexity, so many modern designs will have to be completed by a CAD operator because they are too complex to be drawn on a board.

d. Latest statistics from the Department of Labor indicate that in the early 90s, the median annual earnings for drafters who worked full time, year round was more than (**$25,000.00**) (**$30,000.00**).

e. Modern drafters will continue to be subject to eye strain and back discomfort from sitting long hours at a drawing board or spending long stretches at a computer terminal, but drafters usually work in clean, well-lighted areas with the seasonal comforts of (**home**) (**heating and air conditioning**).

f. Electronic drafters are not confined to working in a single industry; the variety of industries employing electronic drafters includes automotive, aerospace, computer, (**oil companies**) (**communications**), consumer products, and many more.

4. Select true statements about guidelines for planning an electronic drafting career. Place an "X" beside each true statement.

______a. Keep your grades at least average in high school, and make sure you get a high school diploma.

______b. Get started with your drafting career as early as possible by taking courses at your high school or area vocational school.

______c. Concentrate from the very first on developing your CAD skills; board drafting will be much easier after you learn CAD.

______d. Remember that all drafting, especially CAD, has a mathematical base, so take at least a year of algebra and a year of geometry.

______e. Prepare your own options for advancement by taking engineering courses and science courses related to drafting and electronics.

Written Test

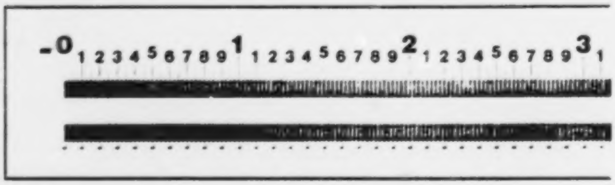
5. Select true statements about guidelines for becoming a good CAD operator. Place an "X" beside each true statement.

   ______a. Polish your skills at using the compasses, dividers, triangles, and other devices required in board drafting; developing these skills will expose you to many principles that you will need as a CAD operator.

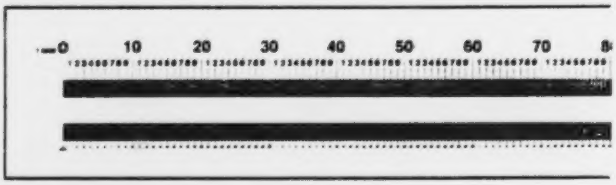
   ______b. Take a typing course or teach yourself to type because keyboarding skills are often required in CAD operations.

   ______c. Learn enough about computers, hardware, and software that you feel comfortable in a high tech environment; and take as many writing courses as your high school or area vocational school offer.

6. Identify precision measuring equipment used in electronic drafting. Write the proper name of the equipment in the blank below each illustration.



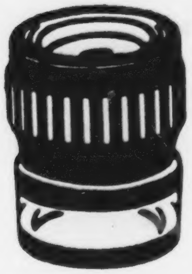
a. ______________________________

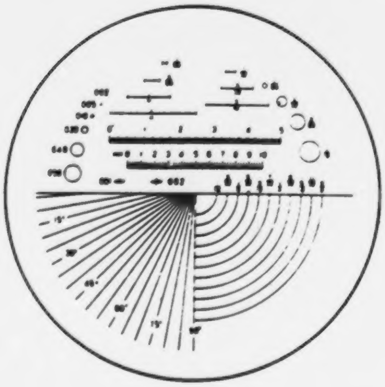


b. ______________________________

Courtesy Bishop Graphics

Written Test





c. ____________________ d. ____________________

Courtesy Bishop Graphics

7. Complete statements about special templates and their uses in electronic drafting. Circle the material that best completes each of the following statements.

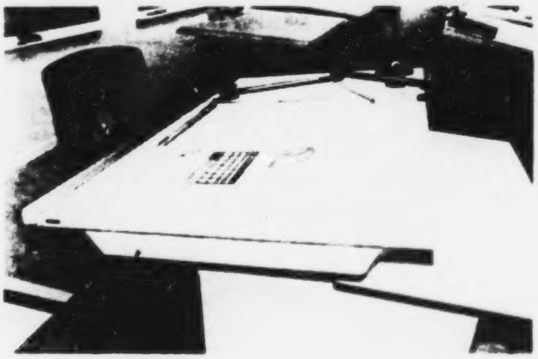
   a. When working with schematics, use templates with electronic or (**standard**) (**logic**) symbols.

   b. When working with PCB (**schematics**) (**layouts**), use templates made especially for PC design.

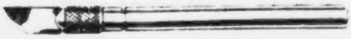
   c. For general drafting, (**general**) (**combination**) templates are the ones used most often, but always use templates that will retain quality and save time.

Written Test

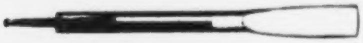
8. Identify other tools used by electronic drafters. Place the name of the tool in the blank below its illustration.



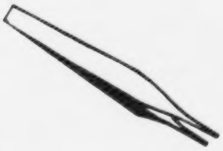
a. ____________________



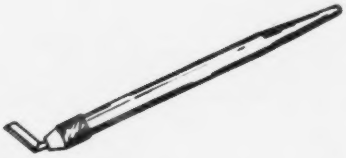
b. ____________________



c. ____________________



d. ____________________



e. ____________________

Courtesy Bishop Graphics

Written Test

9. Complete statements about guidelines for using graphic aids. Circle the material that best completes each of the following statements.

   a. Use transfer letters, numbers, and shapes to retain consistency and (**standard graphics**) (**speed**) because they peel off and stick on with ease.

   b. Use (**components**) (**logic**) symbols just like transfer letters, and you will find they are packaged in handy sheets that make selection easy.

   c. In addition to transfer letters, you may complete electronic graphics free hand or use a lettering device such as a (**Leroy lettering set**) (**transfer kit**).

   d. Create graphic entities that you cannot readily find, and this can be done by using a typewriter, making a template, or using a computer printer or (**plotter**) (**by hand**).

   e. Use (**vellum**) (**standard drawing sheets**) for drawings whether you're on the board or at a CAD station; (**standard drawing sheets**) (**vellum**) continues to be the media of choice for neat, final drawings.

10. Select true statements about the importance of references in electronic drafting. Place an "X" beside each true statement.

______a. References are those publications that provide general guidelines or actual specifications for schematics and drawings produced on a board or with a CAD system.

______b. Two important basic references for professional standards include materials from ANSI, the American National Standards Institute, and IPC, the Institute of Printed Circuits.

______c. Along with national institutes, other professional standards come from many commercial institutions, military standards come from the Department of Defense, and many companies have their own in-house standards.

______d. Other valuable sources include handbooks, dictionaries, and electronic data books; these are typically materials that are frequently updated to keep pace with the fast changing electronics industry.

______e. Manufacturers' catalogs are not really good references, but they are good for addresses and product descriptions.

Written Test

11. Match elements of electronic drafting with their characteristics. Place the number beside the element in the blank beside the description of its characteristic.

______a. A comprehensive list of all components in a circuit or assembly along with their description and vendor's part number

______b. Places groups of components with related functions into easy-to-read blocks, but does not identify individual components

______c. Shows traditional electrical symbols on rails and rungs to represent buttons, switches, relays, and other electrical components

______d. Shows the arrangement and interconnection of logic gates that make up a circuit, but does not show power and ground connections

______e. The final plot or drawing that shows all the artwork required to manufacture a printed circuit board

______f. A system that references common points on multiple layers of a drawing so that all parts of the drawing can be aligned

______g. Shows all electronic components and how they are interconnected within a circuit without regard to actual physical placement of components

1. Master pattern
2. Ladder diagram
3. Registration system
4. BOM
5. Schematic diagram
6. Logic diagram
7. Block diagram

***Permission to duplicate this test is granted.**

Introduction to
Electronic Drafting With CAD
Unit 1

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Draw a Finished Schematic From an Engineer's Sketch Using Templates and a CAD System Rating _____

Comments: ____

____

Assignment Sheet 2—Copy a Schematic Using Manual Techniques With Electronic Templates or on a CAD System Rating _____

Comments: ____

____

Assignment Sheet 3—Redraw and Label a CAD-generated Schematic Rating _____

Comments: ____

____

Assignment Sheet 4—Sketch Pin Configurations and Gate Locations of Selected Chips Rating _____

Comments: ____

____

Assignment Sheet 5—Sketch the Mechanical Configurations of Selected Electronic Components Rating _____

Comments: ____

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______. Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

Introduction to Electronic Drafting With CAD
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **BOM (Bill of Materials)** — An itemized list of parts shown with an assembly drawing

   b. **Brunisher** — A tool for rubbing letters, numbers, and symbols from transfer sheets onto drawings

   c. **Electronic drafting** — Drafting specialized for developing schematics, logic diagrams, ladder diagrams, master patterns, marking drawings, and assembly drawings for use in the electronic industry

   d. **Optical comparator** — A magnifier used for closely checking PCB conductor spacing and width, measured in millimeters and inches

   e. **Pen plotter** — An output device used to print a precision copy of a drawing created on a CAD system

   f. **Pin registration system** — A method for correctly aligning multiple layers used to make a single drawing

   g. **PCB (Printed Circuit Board)** — A nonconductive common base material with a conductive material laminated on one or more sides with a pattern designed to interconnect electronic components

   h. **Reticle** — A system of lines, dots, cross hairs, or wires in the focus of the eyepiece of an optical instrument

   i. **Schematic** — A wiring diagram showing all the components of an electronic circuit and how the components are connected, but the diagram does not show true size, shape, or placement

   j. **Template** — A thin, flat, plastic tool with openings representing different shapes and sizes of standard symbols; used to expedite drawing

2. **CAD software and its applications**

   a. General CAD software is used for almost all kinds of general drafting, but is not specifically designed for electronic drafting.

   b. Application-specific software is software designed for specific applications such as electronic drafting.

Information Sheet

c. The basic element of electronic drafting software is that it allows a CAD drafter to create a schematic or PCB design and reproduce it as a print.

d. Application-specific software for electronic drafting is used to draw schematics, design PCBs, and automatically generate a bill of materials.

e. Another advantageous element of application-specific software for electronics is that is usually contains a library of symbols which helps expedite the creation of schematics and PCBs.

3. The career outlook for electronic drafters

a. The demand for almost all kinds of drafters will increase through the year 2005.

b. The demand for drafters experienced in CAD will also increase in the next decade because as CAD systems and software become less expensive, CAD drafting continues to expand.

c. Modern components are decreasing in size and increasing in complexity, so many modern designs will have to be completed by a CAD operator because they are too complex to be drawn on a board.

d. Latest statistics from the Department of Labor indicate that in the early 90s, the median annual earnings for drafters who worked full time, year round was more than $25,000.00.

e. Modern drafters will continue to be subject to eye strain and back discomfort from sitting long hours at a drawing board or spending long stretches at a computer terminal, but drafters usually work in clean, well-lighted areas with the seasonal comforts of heating and air conditioning.

f. Electronic drafters are not confined to working in a single industry; the variety of industries employing electronic drafters includes automotive, aerospace, computer, communications, consumer products, and many more.

4. Guidelines for planning an electronic drafting career

a. Keep your grades above average in high school, and make sure you get a high school diploma.

b. Get started with your drafting career as early as possible by taking courses at your high school or area vocational school.

c. Concentrate at first on developing your skills as a board drafter because good board skills makes it much easier to learn CAD.

Information Sheet

d. Remember that all drafting, especially CAD, has a mathematical base, so take *at least a year of algebra and a year of geometry.*

e. Prepare your own options for advancement by taking engineering courses and science courses related to drafting and electronics.

5. **Guidelines for becoming a good CAD operator**

a. Polish your skills at using the compasses, dividers, triangles, and other devices required in board drafting; developing these skills will expose you to many principles that you will need as a CAD operator.

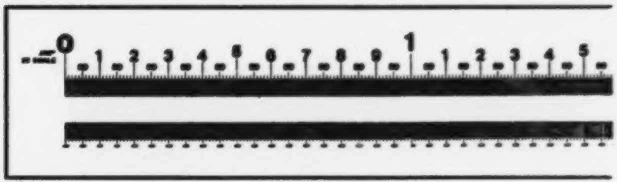
b. Take a typing course or teach yourself to type because keyboarding skills are often required in CAD operations.

c. Learn enough about computers, hardware, and software that you feel comfortable in a high tech environment, and take as many CAD courses as your high school or area vocational school offer.

Note: CAD is a challenge to beginners because of the variety of hardware and the complementing software that makes it all work. Exposure to different kinds of hardware and software can help develop the versatility that CAD operators always need.

6. **Guidelines for using precision measuring scales and instruments**

a. When measuring inches and feet in standard measurements, use a standard 1X, 2X, or 4X scale.

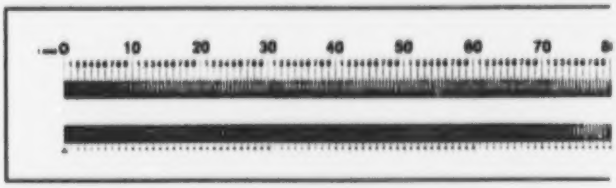


▲ **Use on or with 2X (1" = 2") Scale Artwork**

Courtesy Bishop Graphics

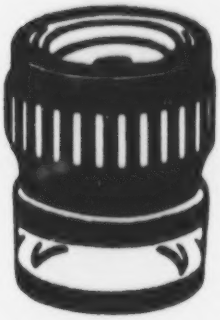
Information Sheet

b. When measuring millimeter or meters, use a metric scale.



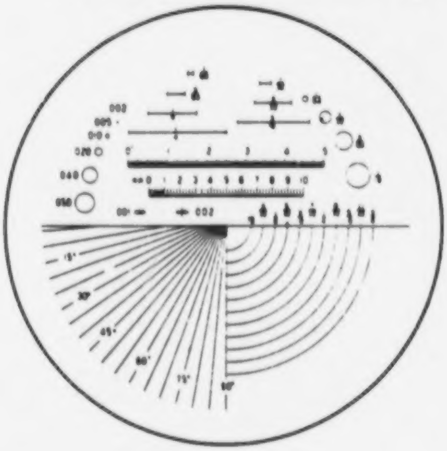
Courtesy Bishop Graphics

c. To enlarge small object or lines for convenient and accurate reference, use a magnifier or an optical comparator.



Courtesy Bishop Graphics

d. To enlarge extremely fine lines for accurate reference, use a reticle.

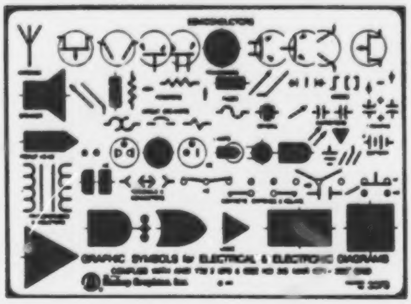


Courtesy Bishop Graphics

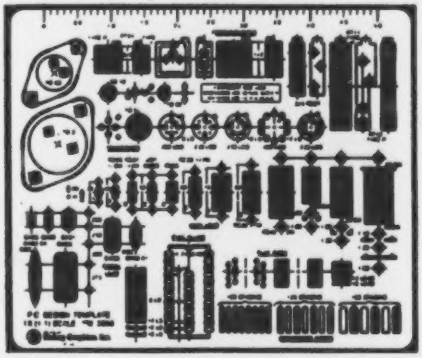
Information Sheet

7. Special templates and their uses in electronic drafting

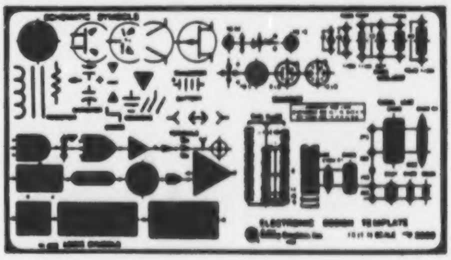
a. When working with schematics, use templates with electronic or logic symbols.


SEMICONDUCTORS
GRAPHIC SYMBOLS for ELECTRICAL & ELECTRONIC DIAGRAMS
Bishop Graphics, Inc.

b. When working with PCB layouts, use templates made especially for PC design.


PC DESIGN TEMPLATE
Bishop Graphics, Inc.

c. For general drafting, combination templates are the ones used most often, but always use templates that will retain quality and save time.

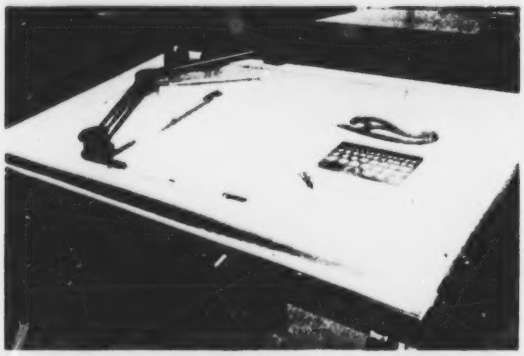

SCHEMATIC SYMBOLS
ELECTRONIC DESIGN TEMPLATE
Bishop Graphics, Inc.

All templates courtesy Bishop Graphics

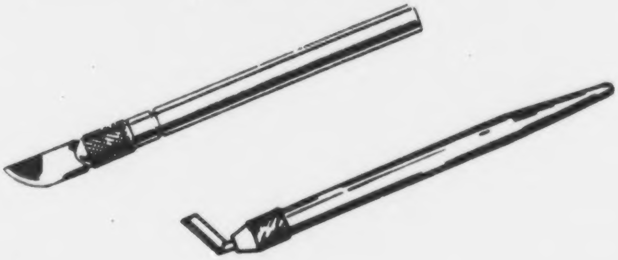
Information Sheet

8. Other electronic drafting tools and their uses

a. A light table provides a lighted background that makes lines and symbols easier to see and work with.

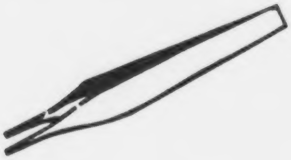


b. A precision cutting knife or swivel knife with an assortment of blades makes it easier to cut in hard-to-reach places.



Courtesy Bishop Graphics

c. Tweezers are handy tools for placing transfer symbols, letters, and shapes onto a drawing, and a burnisher completes the job by sticking transfer items firmly in place.

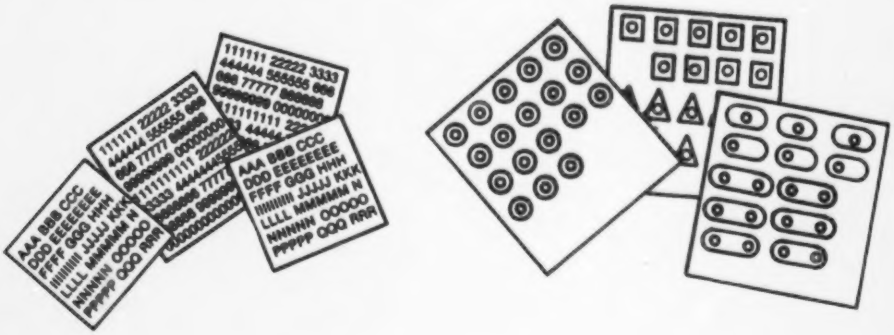


Courtesy Bishop Graphics

Information Sheet

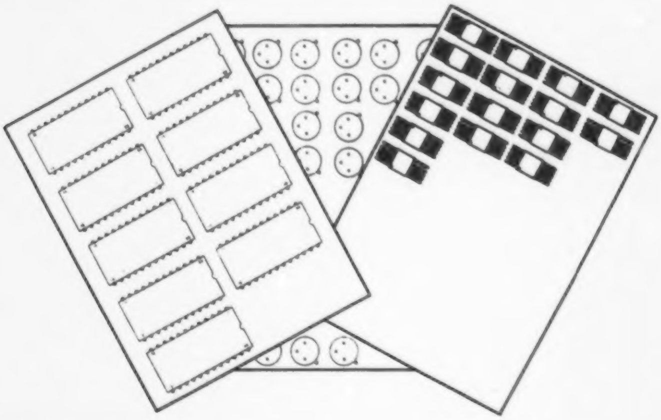
9. Guidelines for using graphic aids

a. Use transfer letters, numbers, and shapes to retain consistency and speed because they peel off and stick on with ease.



Courtesy Bishop Graphics

b. Use components symbols just like transfer letters, and you will find they are packaged in handy sheets that make selection easy.



Courtesy Bishop Graphics

c. In addition to transfer letters, you may complete electronic graphics free hand or use a lettering device such as a Leroy lettering set.

d. Create graphic entities that you cannot readily find, and this can be done by using a typewriter, making a template, or using a computer printer or plotter.

e. Use vellum for drawings whether you're on the board or at a CAD station; vellum continues to be the media of choice for neat, final drawings.

Information Sheet

10. References and their importance in electronic drafting

a. References are those publications that provide general guidelines or actual specifications for schematics and drawings produced on a board or with a CAD system.

b. Two important basic references for professional standards include materials from ANSI, the American National Standards Institute, and IPC, the Institute of Printed Circuits.

c. Along with national institutes, other professional standards come from many commercial institutions, military standards come from the Department of Defense, and many companies have their own in-house standards.

d. Other valuable sources include handbooks, dictionaries, and electronic data books; these are typically materials that are frequently updated to keep pace with the fast changing electronics industry.

e. Manufacturers' catalogs are also excellent reference sources for both graphic and technical materials.

11. Elements of electronic drafting and their characteristics

a. **BOM (Bill of Materials)** — A comprehensive list of all components in a circuit or assembly along with their description and vendor's part number

PARTS LIST	BRYTEK, INC.	CONTRACT NO.
TITLE FSK DECODER, PACKAGE, PCB, COMPONENTS		DRAWING NO.

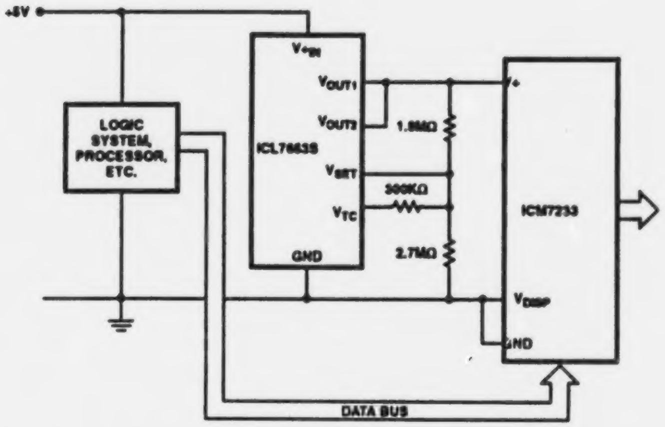
ITEM NO.	QTY	REFERENCE NO.	PART NO.	DESCRIPTION
1	1	U1	LM565	PLL - UNIT
2	1	U2	LM710	COMPARATOR
3	2	R1, R2	68kΩ	1/4W 68kΩ RESISTOR
4	1	R3	5kΩ	1/4W 5kΩ RESISTOR
5	3	R4, R5, R6	10kΩ	1/4W 10kΩ RESISTOR
6	1	C1	0.1μF	0.1μF CAPACITOR
7	1	C2	0.05μF	0.05μF CAPACITOR
8	1	C3	0.01μF	0.01μF CAPACITOR
9	4	C4-C7	0.02μF	0.02μF CAPACITOR
10	1	H1	H1	WIRING HARNESS
11	1	PCB1	PCB1	PRINTED CIRCUIT BOARD
12	1	SCH1	SCH1	SCHEMATIC DIAGRAM

NOTE: OTHER ITEMS MAY BE INCLUDED IN THE BILL OF MATERIALS, INCLUDING PCB LAYOUT, BLOCK DIAGRAM, PLACEMENT DIAGRAM ETC.

CAD NOTE: WHEN USING A COMPUTER PROGRAM SUCH AS HIWIRE TO GENERATE A BILL OF MATERIALS, ONLY THE COMPONENTS WILL BE LISTED. THE DRAFTER WILL HAVE TO ADD ITEMS SUCH AS PCB, HARNESS, DIAGRAMS ETC.

Information Sheet

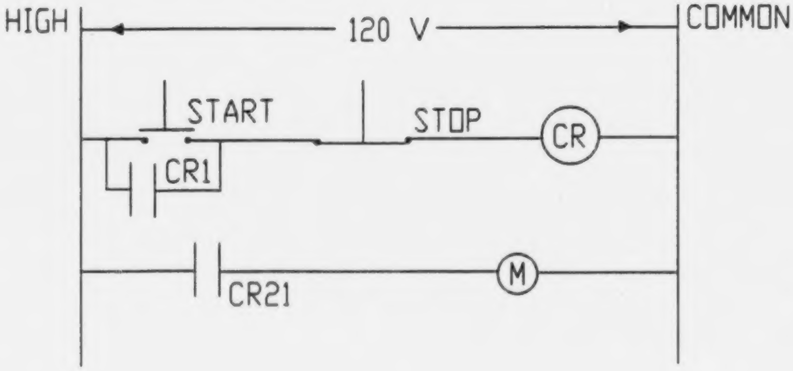
b. **Block diagram** — Places groups of components with related functions into easy-to-read blocks, but does not identify individual components


+5V
LOGIC SYSTEM, PROCESSOR, ETC.
V_{+IN}
V_{OUT1}
V_{OUT2}
ICL7663S
V_{SET}
V_{TC}
GND
1.8MΩ
300KΩ
2.7MΩ
V+
ICM7233
V_{DISP}
GND
DATA BUS

GENERATING A MULTIPLEXED LCD DISPLAY DRIVE VOLTAGE

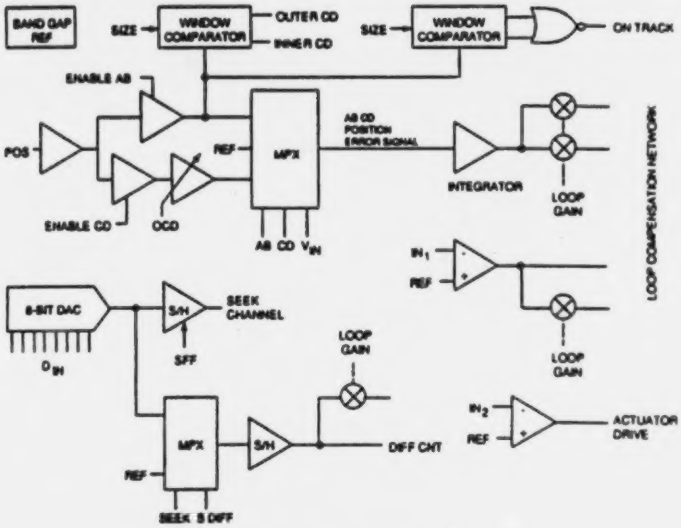
Courtesy Harris Semiconductor. All rights reserved.

c. **Ladder diagram** — Shows traditional electrical symbols on rails and rungs to represent buttons, switches, relays, and other electrical components


HIGH
120 V
COMMON
START
STOP
CR
CR1
CR21
M

Information Sheet

d. **Logic diagram** — Shows the arrangement and interconnection of logic gates that make up a circuit


BAND GAP REF
SIZE
WINDOW COMPARATOR
OUTER CD
INNER CD
SIZE
WINDOW COMPARATOR
ON TRACK
ENABLE AB
POS
REF
MPX
AB CD POSITION ERROR SIGNAL
INTEGRATOR
LOOP GAIN
ENABLE CD
OCD
AB
CD
V_{IN}
IN_1
REF
LOOP COMPENSATION NETWORK
8-BIT DAC
S/H
SEEK CHANNEL
SFF
D_{IN}
LOOP GAIN
LOOP GAIN
MPX
S/H
DIFF CNT
REF
SEEK
S DIFF
IN_2
REF
ACTUATOR DRIVE

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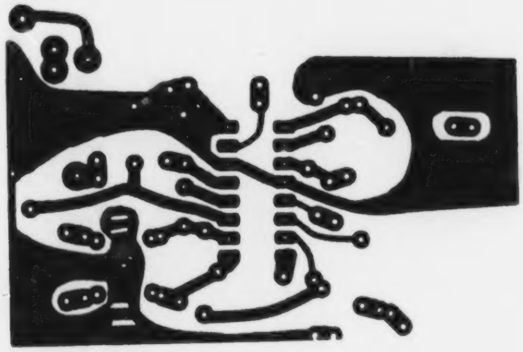
e. **Master pattern** — The final plot or drawing that shows all the artwork required to manufacture a printed circuit board

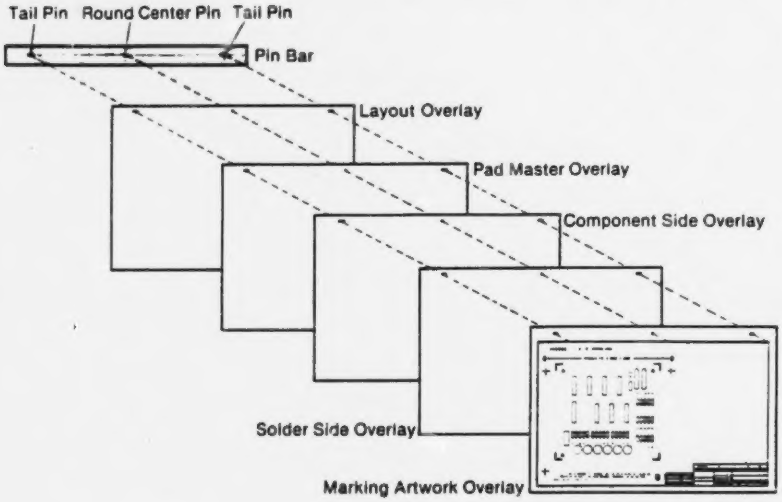


BOTTOM VIEW OF PRINTED CIRCUIT BOARD

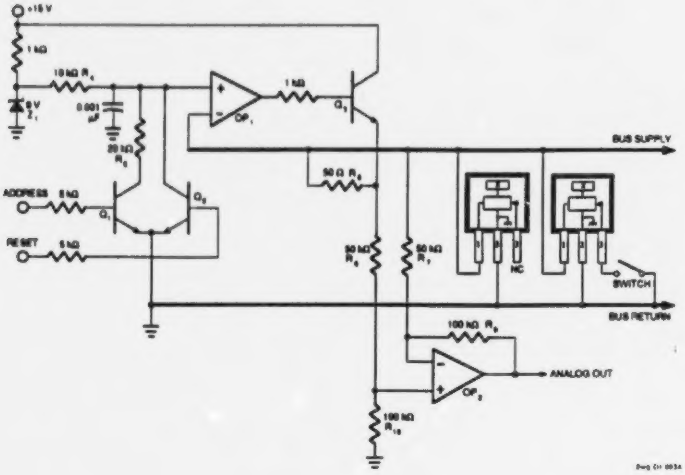
Courtesy Harris Semiconductor. All rights reserved.

Information Sheet

f. **Registration system** — A system that references common points on multiple layers of a drawing so that all parts of the drawing can be aligned


Tail Pin
Round Center Pin
Tail Pin
Pin Bar
Layout Overlay
Pad Master Overlay
Component Side Overlay
Solder Side Overlay
Marking Artwork Overlay

g. **Schematic diagram** — Shows all electronic components and how they are interconnected within a circuit without regard to actual physical placement of components


+15 V
1 kΩ
10 kΩ R1
9V Z1
0.001 µF
20 kΩ R2
1 kΩ
Q3
OP1
BUS SUPPLY
50 Ω R5
ADDRESS 5 kΩ
Q1
Q2
RESET 5 kΩ
50 kΩ R6
50 kΩ R7
NC
SWITCH
BUS RETURN
100 kΩ R9
ANALOG OUT
OP2
100 kΩ R10

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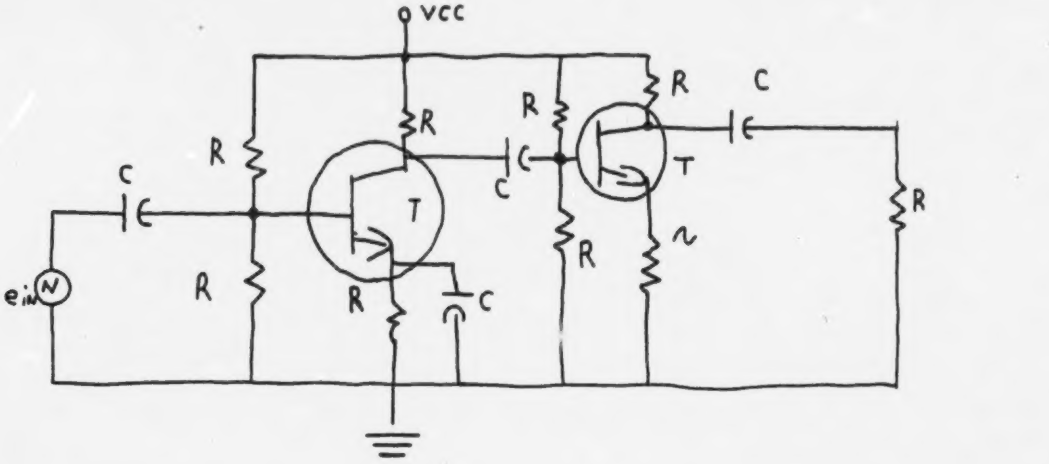
Introduction to
Electronic Drafting With CAD
Unit 1

Assignment Sheet 1—Draw a Finished Schematic From an Engineer's Sketch Using Templates or a CAD System

Name ______________________ Overall Rating ________

Evaluation Criteria	Rating
All lines clean and straight	______
All symbols drawn neatly with a template or CAD system	______
Labels neat and easy to read	______

Directions: Draw a finished schematic on vellum from the engineer's sketch that follows. Use either manual drafting techniques and a template, or a CAD system.



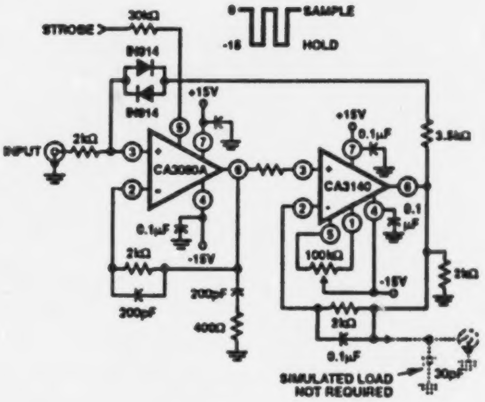
Introduction to Electronic Drafting With CAD
Unit 1

Assignment Sheet 2—Copy a Schematic Using Manual Techniques With Electronic Templates or on a CAD System

Name ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
All lines clean and straight	______
All symbols drawn neatly with a template or CAD system	______
Labels neat and easy to read	______

Directions: Copy the finished schematic below using appropriate drafting media and electronic templates. Enlarge to fit appropriate media.


30kΩ
STROBE
0
SAMPLE
-15
HOLD
1N914
1N914
+15V
INPUT
2kΩ
3
2
5
7
CA3080A
6
4
0.1μF
-15V
2kΩ
200pF
200pF
400Ω
+15V
0.1μF
7
3
CA3140
6
2
4
5
1
0.1 μF
100kΩ
-15V
3.9kΩ
2kΩ
2kΩ
0.1μF
SIMULATED LOAD NOT REQUIRED
30pF

SAMPLE AND HOLD CIRCUIT

Courtesy Harris Semiconductor. All rights reserved.

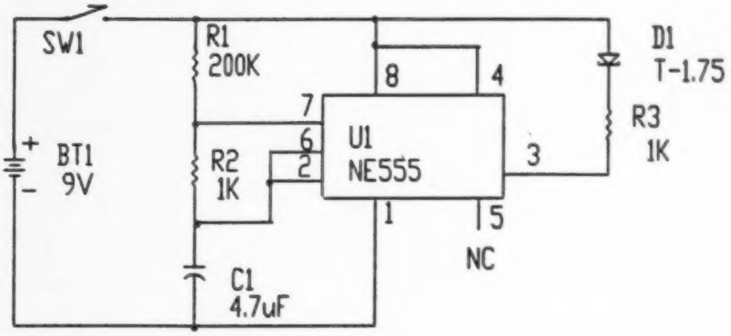
Introduction to Electronic Drafting With CAD
Unit 1

Assignment Sheet 3—Redraw and Label a CAD-Generated Schematic

Name ______________________________ Overall Rating ________

Evaluation Criteria	Rating
All lines clean and straight	______
All symbols drawn neatly with a template or CAD system	______
Labels neat and easy to read	______

Directions: Redraw and label the following schematic. Use templates if you use manual techniques, or library symbols if you're using a CAD system.


SW1
R1
200K
8
4
D1
T-1.75
7
6
2
U1
NE555
3
R3
1K
+
BT1
9V
-
R2
1K
1
5
NC
C1
4.7uF

Introduction to
Electronic Drafting With CAD
Unit 1

Assignment Sheet 4—Sketch the Pin Configurations and Gate Locations of Selected Chips

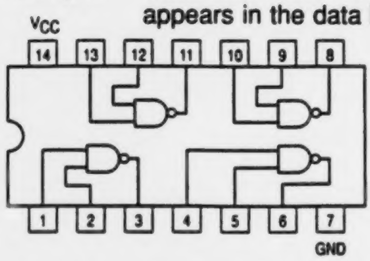
Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
All pins and gates indicated	______
All symbols drawn neatly	______
Numbers and letters neat and easy to read	______

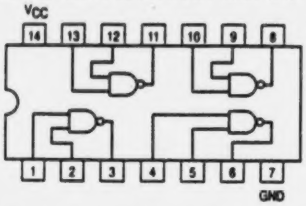
Directions: Sketch the pin locations and gate locations for the following Motorola chips. Use the Motorola graphics as a guide to copy from.

> **CAD Alert:** This is an excellent assignment to complete at a CAD stattion. Since all the chips are the same shape and have the same number of pins, once you save your basic configuration, you have to draw only the logic gates.

Example: Motorola's MC54/74F00 QUAD 2-INPUT NAND GATE FAST™ SCHOTTKY TTL appears in the data book like this:



When you redraw the chip, it should look as much like the original as possible.



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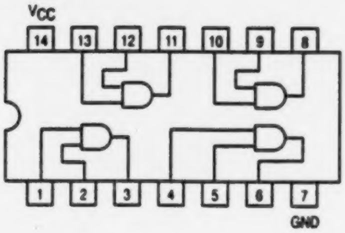
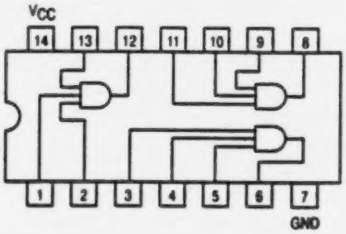
Assignment Sheet 4

Note: You may place your drawings in the blank spaces below or keep them together with proper numbers so your instructor can evaluate your drawings.

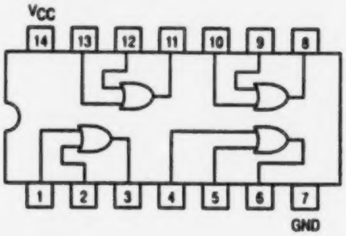
Sketch 1: Motorola SN54/74LS08


VCC
14
13
12
11
10
9
8
1
2
3
4
5
6
7
GND

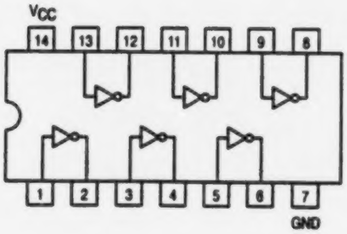
Sketch 2: Motorola SN54/74LS11


VCC
14
13
12
11
10
9
8
1
2
3
4
5
6
7
GND

Sketch 3: Motorola SN54/74LS32


VCC
14
13
12
11
10
9
8
1
2
3
4
5
6
7
GND

Sketch 4: Motorola SN54/74LS04


VCC
14
13
12
11
10
9
8
1
2
3
4
5
6
7
GND

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Introduction to
Electronic Drafting With CAD
Unit 1

Assignment Sheet 5—Sketch the Mechanical Configurations of Selected Electronic Components

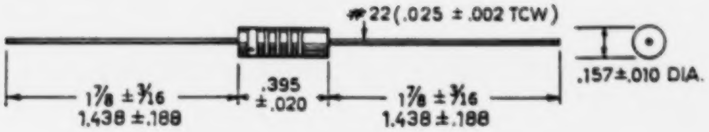
Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
All sketches complete and correct	______
All symbols drawn neatly with a template or CAD system	______
Lettering neat and easy to read	______

Directions: Sketch the mechanical configurations for the selected electronic components listed in the problems that follow. Use reference materials as provided by your instructor, and if you're using a CAD system, locate and identify the symbol for each component.

Example: 15µ H RF induction choke

Answer:



Problems:

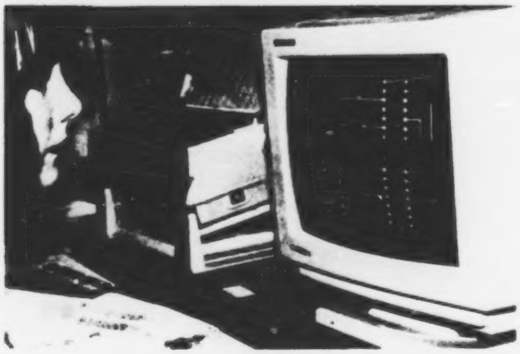
A. 10K ¼ Watt Resistor

B. TO-39 Transistor Package
(2N5415 or 2N5322)

Assignment Sheet 5

C. 100K Rectangular Trimmer SIP Potentiometer

D. Sub-Miniature SPDT Toggle Switch, PC Mount



CAD Systems and Software
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to locate and identify parts of a CAD system, and locate, print, and sketch items from symbol libraries. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to CAD systems and software with their correct definitions.
2. Match general CAD commands for PCB layout with their definitions.
3. Match specific CAD commands for PCB layout with their definitions.
4. Select true statements about major CAD applications for electronic drafting.
5. Select CAD system input data required for PCB layout.
6. List types of output generated by a CAD system.
7. Complete statements about types of hardware used in a CAD workstation.
8. Match operator input devices with their uses.
9. Arrange in order the steps in CAD-developed documentation.
10. Select true statements about available turnkey CAD systems.
11. Locate and identify parts of a CAD system. (Assignment Sheet 1)
12. Locate, print, and sketch items from symbol libraries. (Assignment Sheet 2)

CAD Systems and Software
Unit 2

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Make a transparency out of Transparency Master 1 that comes with this unit. TM 1 is designed to be used with Objective 9.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.
11. Discuss and demonstrate the procedures in the job sheets, and obtain any special tools and materials required.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Use Objective 7 to impress upon students the importance of matching hardware and software in relation to the work a CAD station or system will be asked to produce. Tie this objective in with Assignment Sheet 1. Skill areas: **Learning skills, learning to learn.**

2. Have documents, schematics, drawings, or other materials available to show the kinds of output generated by a CAD system. Point out the advantages and limitations of each output device. Skill areas: **Learning skills, learning to learn.**

3. Demonstrate input devices discussed in Objective 8, and point out that certain input devices function best with certain applications. **Learning skills, learning to learn.**

4. Discuss and demonstrate the objectives of Assignment Sheet 2. Assign students to small teams of two or three to examine various libraries. Have them report to the class items in the library that make it particularly useful. Skill areas: **Group effectiveness skills, teamwork.**

Suggested Activities

Resources Used in Developing This Unit

1. Coombs, Clyde F. Jr. *Printed Circuits Handbook*, 3rd ed. NY: McGraw-Hill, 1988.

2. Raskhonoff, Nicholas M. *Electronic Drafting and Design*, 5th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1988.

3. Villanocci, Robert S., et al. *Electronic Techniques, Shop Practices, and Construction.* Englewood Cliffs, NJ: Prentice-Hall International, 1986.

Suggested Supplemental Resources

1. *HIWIRE II* is a popular CAD package developed especially for electronic drafting. *HIWIRE II* is available at a 50% discount for educational institutions. For package details and pricing information, call 1-800-742-6809, or write:

   Wintek Corporation
   1801 South Street
   Lafayette, IN 47904-2993

2. **PADS Software, Inc.** has a sophisticated CAD package for schematic capture and PC board layout. The software is available to educational institutions at 50% off regular retail. A demonstration of the software is contained in a **"Shareware Kit."** For information, call 1-800-554-7253, Extension 4 for information, or write:

   PADS Software
   119 Russel Street
   Littleton, MA 01460

CAD Systems and Software
Unit 2

Answers to Assignment Sheets

Assignment Sheets 1 and 2

Evaluated according to criteria written in the respective assignment sheets.

CAD Systems and Software
Unit 2

Answers to Written Test

1.
a. 6
b. 8
c. 16
d. 13
e. 10
f. 4
g. 1
h. 7
i. 14
j. 12
k. 9
l. 5
m. 15
n. 11
o. 2
p. 3

2.
a. 5
b. 3
c. 7
d. 1
e. 4
f. 2
g. 6

3.
a. 1
b. 5
c. 4
d. 2
e. 6
f. 3

4. a, b, d, e, f

5. a, b, c, d, f

6. Any seven of the following in any order:

a. Master pattern artwork
b. Marking artwork such as silkscreen
c. Assembly drawings
d. Solder resist artwork
e. Pads only drilling master
f. Numerical control (NC) drilling tape
g. Numerical control (NC) automatic insertion tape
h. Logic tester tape
i. Bill of materials
j. Check plots
k. Wire wrap data
l. Schematic and logic diagrams

7.
a. Several display terminals
b. Light pen
c. Laser printer

8.
a. 4
b. 6
c. 2
d. 1
e. 5
f. 3

Answers to Written Test

9.
a.	8	d.	1	g.	10	j.	12
b.	3	e.	5	h.	4	k.	9
c.	6	f.	2	i.	7	l.	11

10. a, b

CAD Systems and Software
Unit 2

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. A CAD system which automatically routes traces between components

______b. A second copy of CAD-developed work on tape or disc

______c. A process that uses a computer to create or modify a design

______d. An alphabetical, numeric, or special graphic symbol

______e. A symbol which has a physical meaning such as resistor or transistor

______f. A point on a display where horizontal and vertical lines intersect to indicate a desired coordinate

______g. The actual data created by the CAD software as a schematic or PCB layout is drafted on the computer

______h. Any line, circle, arc, label, or note

______i. List of options or commands on a computer screen; they may be selected with a mouse, keyboard, or digitizing tablet

______j. One one thousandth (1/1000) of an inch

______k. A round or rectangular conductor, typically at the end of a trace, where a lead of an electronic component is soldered

1. Drawing file
2. Trace
3. Turnkey
4. Cross hairs
5. Paper size
6. Autorouting
7. Entity
8. Backup
9. Pad
10. Component symbol
11. Scale
12. MIL
13. Character
14. Menu
15. PCB symbol
16. CAD

Written Test

______l. ANSI standard paper sizes expressed as a letter size such as 8 1/2″ × 11″ or 11″ × 17″, representing sizes A and B

______m. A group of pads placed with concise spacing to accommodate a particular electronic component package

______n. The magnification factor such as 1X, 4X, used when plotting a PCB layout

______o. A conductor path that connects components on a PCB or PCB layout

______p. A computer or CAD system sold in such a state of readiness that it can be turned on and used immediately because it includes both hardware and software

2. Match general CAD commands for PCB layout with their definitions. Place the number beside the command in the blank beside its definition.

______a. The pattern of dots displayed on a screen so that a drafter can set grids to a known value to utilize it like a scale when drafting

______b. Each single level of a PCB

______c. A command that allows a drafter to select which library the software searches for symbols

______d. A command used to draw pads of various sizes and shapes

______e. A function of a CAD system that causes any entity placed on the drawing to "snap" into place at the nearest grid point or dot

______f. A command that sets the width of traces in mils

1. Pad
2. Width
3. Layer
4. Snap
5. Grid
6. Zoom
7. Library

Written Test

______g. A command that allows a drafter to zoom in to enlarge a location on a drawing or to zoom out to give a drafter a larger view of the drawing

3. Match specific commands for PCB layout with their definitions. Place the number beside the command in the blank beside its definition.

______a. A command used to connect a group of pads in order to create a symbol

______b. A command used to change the side of the symbol that is facing the screen

______c. A command used to "unbind" a symbol so that deletions or changes to the symbol can be made

______d. A command used to rotate symbols; this command rotates a symbol 45° clockwise each time it is selected

______e. A command used to place a symbol from a symbol library onto a drawing

______f. A conductor path that connects components on a PCB or on a PCB layout

1. Bind
2. Spin
3. Trace
4. Free
5. Flip
6. Symbol

4. Select true statements about major CAD applications for electronic drafting. Place an "X" beside each true statement.

______a. In general, CAD software saves time and improves accuracy when it performs activities like compiling a bill of materials.

______b. Autocontinuity is a time saver because it checks the PCB layout with the schematic diagram and isolates errors.

______c. Good CAD software can make good schematic drawings, but doesn't do well on other types of drawings and diagrams.

______d. Autorouting optimizes trace locations, and there are other design checks for minimum width and spacing of traces.

Written Test

______e. CAD software creates geometric constructions such as arcs, lines, and special shapes.

______f. Automatic component placement on PCB layouts optimizes the process.

5. Select CAD system input data required for PCB layout. Place an "X" beside each item that qualifies as input data.

______a. Net list

______b. Board outline drawing

______c. Components for bill of materials

______d. Dimensional information

______e. Correction numbers

______f. Special applications from CAD system library data files

6. List seven types of output generated by a CAD system. Items may be listed in any order.

a. ____________________________

b. ____________________________

c. ____________________________

d. ____________________________

e. ____________________________

f. ____________________________

g. ____________________________

Written Test

7. Complete statements about types of hardware used in a CAD workstation. Circle the material that best completes each of the following statements.

   a. A CAD workstation may have a color or black and white CRT display, and the station may have (**several display terminals**) (**several dumb terminals**).

   b. Workstation input devices include an alphanumeric keyboard, function keyboard, graphics tablet, (**modem**) (**light pen**), and a multi-button mouse.

   c. Workstation output devices include a (**dot matrix**) (**laser printer**), a bed plotter, an electrostatic plotter, a digitizer plotter, and a photoplotter.

8. Match operator input devices with their uses. Place the number beside the input device in the blank beside the description of its use.

______a. Used to enter commands, symbols, and nongraphic data, and also used to request information from a system

______b. Used as a digital device to generate movement of a cursor or cross hair up or down, left or right, or to transmit memory file content back to a hose computer

______c. Used with a symbol menu overlay to develop designs with a stylus, hand-held cursor, or mouse

______d. Used to generate cursor movement in X and Y directions simultaneously

______e. Used to generate cursor movement in X and Y directions simultaneously

______f. Used on refresh tubes to generate a computer interrupt that allows an operator to input coordinates from the screen by pointing ont the screen

1. Joystick
2. Graphics tablet
3. Light pen
4. Alphanumeric keyboard
5. Trackball
6. Function keyboard

Written Test

9. Arrange in order the steps in CAD-developed documentation. Place a 1 beside the first step, a 2 beside the second step, and complete the other steps in order.

______a. Interactively clean up or edit PCB.

______b. Extract the element list.

______c. Determine automatic PCB routing.

______d. Obtain the original schematic.

______e. Determine automatic placement and improvement by using the company standards PCB library and optional placement improvement.

______f. Input the schematic using the symbol library specified by company standards.

______g. List signal nets on PCB.

______h. Determine automatic gate and pin assignment by using the physical component description file.

______i. Evaluate PCB and reconnect, if desired.

______j. Obtain output or outputs.

______k. Automatically compare PCB and net list.

______l. Automatically check geometric design.

10. Select true statements about available turnkey CAD systems. Place an "X" beside each true statement.

______a. Several companies either manufacture or assemble turnkey CAD systems dedicated to PC board layout and electronic drafting.

______b. Turnkey CAD systems are literally ready to turn on and operate because they include not only the major system hardware, but also integrated software to make everything work.

______c. Turnkey CAD systems are so complete that they seldom require any modification.

***Permission to duplicate this test is granted.**

CAD Systems and Software
Unit 2

Unit Evaluation Form

Student Name ________________________ Unit Rating __________

Assignment Sheet 1—Locate and Identify Parts of a CAD System Rating _____

Comments: ____

____

Assignment Sheet 2—Locate, Print, and Sketch Items From Symbol Libraries Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

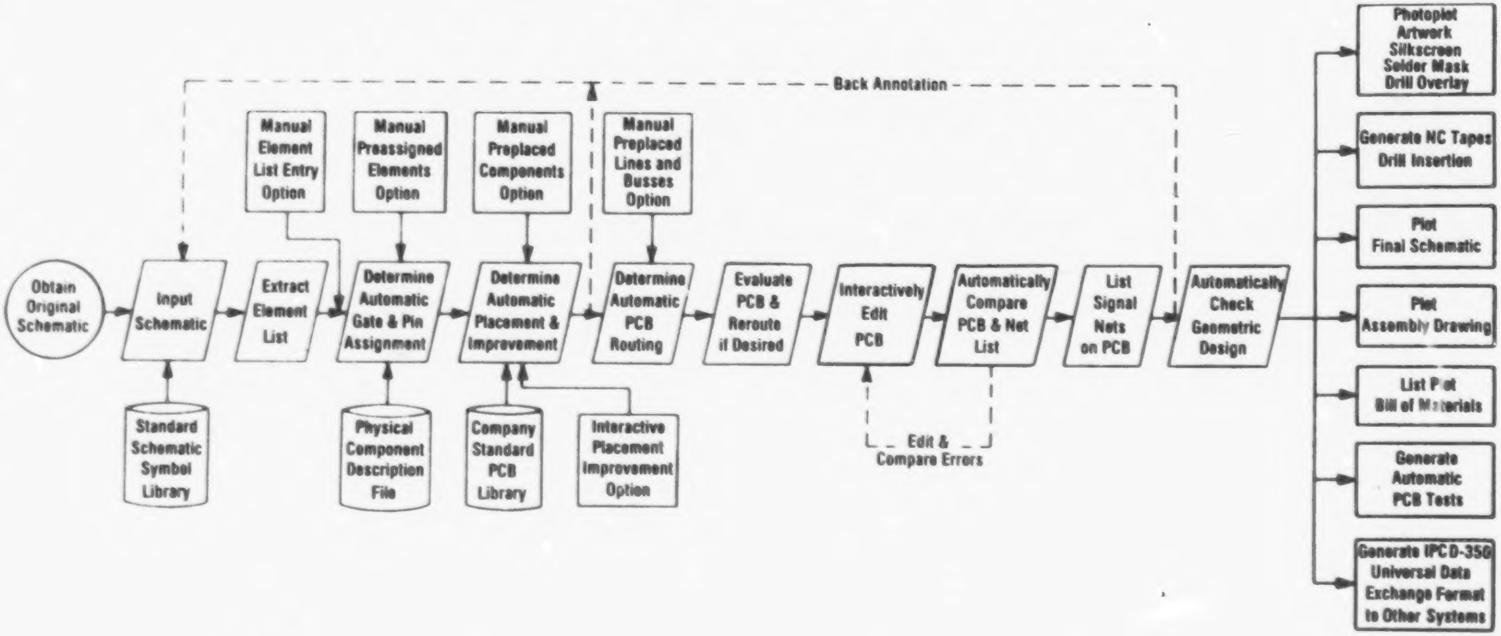
____

Teacher Signature ________________________ Date __________

Student Signature ________________________ Date __________

*Permission to duplicate this form is granted.

CAD Electronic Design and Documentation Process



Back Annotation

Obtain Original Schematic

Input Schematic

Standard Schematic Symbol Library

Manual Element List Entry Option

Extract Element List

Manual Preassigned Elements Option

Determine Automatic Gate & Pin Assignment

Physical Component Description File

Manual Preplaced Components Option

Determine Automatic Placement & Improvement

Company Standard PCB Library

Interactive Placement Improvement Option

Manual Preplaced Lines and Busses Option

Determine Automatic PCB Routing

Evaluate PCB & Reroute if Desired

Interactively Edit PCB

Automatically Compare PCB & Net List

Edit & Compare Errors

List Signal Nets on PCB

Automatically Check Geometric Design

Photoplot Artwork Silkscreen Solder Mask Drill Overlay

Generate NC Tapes Drill Insertion

Plot Final Schematic

Plot Assembly Drawing

List Plot Bill of Materials

Generate Automatic PCB Tests

Generate IPC D-350 Universal Data Exchange Format to Other Systems

CAD Systems and Software
Unit 2

Information Sheet

1. **Terms and definitions**
   a. **Autorouting** — A CAD system which automatically routes traces between components
   b. **Backup** — A second copy of CAD-developed work on tape or disc
   c. **CAD (Computer Aided Design)** — A process that uses a computer to create or modify a design
   d. **Character** — An alphabetical, numeric, or special graphic symbol
   e. **Component symbol** — A symbol which has a physical meaning such as resistor or transistor
   f. **Cross hairs** — A point on a display where horizontal and vertical lines intersect to indicate a desired coordinate
   g. **Drawing file** — The actual data created by the CAD software as a schematic or PCB layout is drafted on the computer
   h. **Entity** — Any line, circle, arc, label, or note
   i. **Menu** — List of options or commands listed on a computer screen; they may be selected with a mouse, keyboard, or digitizing tablet
   j. **MIL** — One one thousandth (1/1000) of an inch
   k. **Pad** — A round or rectangular conductor, typically at the end of a trace, where a lead of an electronic component is soldered
   l. **Paper size** — ANSI standard paper sizes expressed as a letter size such as 8 1/2" × 11" or 11" × 17", representing sizes A and B
   m. **PCB symbol** — A group of pads placed with concise spacing to accommodate a particular electronic component package
   n. **Scale** — The magnification factor such as 1X, 4X, used when plotting a PCB layout
   o. **Trace (TRC)** — A conductor path that connects components on a PCB or PCB layout
   p. **Turnkey** — A computer or CAD system sold in such a state of readiness that it can be turned on and used immediately because it includes both hardware and software

Information Sheet

2. **General CAD commands for PCB layout and their definitions**

   a. **Grid** — The pattern of dots displayed on a screen so that a drafter can set grids to a known value to utilize it like a scale when drafting

   b. **Layer** — Each single level of a PCB

   c. **Library** — A command that allows a drafter to select which library the software searches for symbols

      Example: To locate a .25 watt transistor with HiWire software, set the library to "PCB.LIB."

   d. **Pad** — A command used to draw pads of various sizes and shapes

      Example: To create a pad for the positive and ground terminals to connect to a PCB, use a "PAD" command.

   e. **Snap** — A function of a CAD system that causes any entity placed on the drawing to "snap" into place at the nearest grid point or dot

   f. **Width** — A command that sets the width of traces in mils

   g. **Zoom** — A command that allows a drafter to zoom in to enlarge a location on a drawing or to zoom out to give a drafter a larger view of the drawing

3. **Specific commands for PCB layout and their definitions**

   a. **Bind** — A command used to connect a group of pads in order to create a symbol

   b. **Flip** — A command used to change the side of the symbol that is facing the screen

   c. **Free** — A command used to "unbind" a symbol so that deletions or changes to the symbol can be made

   d. **Spin** — A command used to rotate symbols; this command rotates a symbol 45° clockwise each time it is selected

   e. **Symbol** — A command used to place a symbol from a symbol library onto a drawing

   f. **Trace (TRC)** — A conductor path that connects components on a PCB or on a PCB layout

Information Sheet

4. **Major CAD applications for electronic drafting**

    a. In general, CAD software saves time and improves accuracy when it performs activities like compiling a bill of materials.

    b. Autocontinuity is a time saver because it checks the PCB layout with the schematic diagram and isolates errors.

    c. Good CAD software can make a variety of drawings, including schematics, logic diagrams, and cable diagrams.

    d. Autorouting optimizes trace locations, and there are other design checks for minimum width and spacing of traces.

    e. CAD software creates geometric constructions such as arcs, lines, and special shapes.

    f. Automatic component placement on PCB layouts optimizes the process.

5. **CAD system input data required for PCB layout**

    a. Net list

    Note: The net list is generated from the schematic.

    b. Board outline drawing

    c. Components for bill of materials

    d. Dimensional information

    Example: Trace widths and spacings

    f. Special applications from CAD system library data files

    Example: Keep out areas, fixed race, and component location

6. **Types of output generated by a CAD system**

    a. Master pattern artwork

    b. Marking artwork such as silkscreen

    c. Assembly drawings

    d. Solder resist artwork

Information Sheet

e. Pads only drilling master

f. Numerical control (NC) drilling tape

g. Numerical control (NC) automatic insertion tape

h. Logic tester tape

i. Bill of materials

j. Check plots

k. Wire wrap data

l. Schematic and logic diagrams

7. **Types of hardware used in a CAD workstation**

   a. A CAD workstation may have a color or black and white CRT display, and the station may have several display terminals.

   b. Workstation input devices include an alphanumeric keyboard, function keyboard, graphics tablet, light pen, and a multi-button mouse.

      Note: See Objective 8 for more information about input devices.

   c. Workstation output devices include a laser printer, a bed plotter, an electrostatic plotter, a digitizer plotter, and a photoplotter.

8. **Operator input devices and their uses**

   a. **Alphanumeric keyboard** — Used to enter commands, symbols, and nongraphic data, and also used to request information from a system

   b. **Function keyboard** — Used as a digital device to generate movement of a cursor or cross hair up or down, left or right, or to transmit memory file content back to a hose computer

      Note: In some applications, the functions of buttons are included in a user-selectable menu to direct a cursor.

   c. **Graphics tablet** — Used with a symbol menu overlay to develop designs with a stylus, hand-held cursor, or mouse

   d. **Joystick** — Used to generate cursor movement in X and Y directions simultaneously

Information Sheet

   e. **Trackball** — Used to generate cursor movement in X and Y directions simultaneously

   f. **Light pen** — Used on refresh tubes to generate a computer interrupt that allows an operator to input coordinates from the screen by pointing ont the screen

9. Steps in CAD-developed documentation

   a. Obtain the original schematic.

   b. Input the schematic using the symbol library specified by company standards.

   c. Extract the element list.

   d. Determine automatic gate and pin assignment by using the physical component description file.

   e. Determine automatic placement and improvement by using the company standards PCB library and optional placement improvement.

   f. Determine automatic PCB routing.

   g. Evaluate PCB and reconnect, if desired.

   h. Interactively clean up or edit PCB.

   i. Automatically compare PCB and net list.

   j. List signal nets on PCB.

   k. Automatically check geometric design.

   l. Obtain output or outputs.

10. Available turnkey CAD systems

   a. Several companies either manufacture or assemble turnkey CAD systems dedicated to PC board layout and electronic drafting.

   b. Turnkey CAD systems are literally ready to turn on and operate because they include not only the major system hardware, but also integrated software to make everything work.

Information Sheet

c. Although they are complete, turnkey CAD systems are often modified to meet company output requirements, and software is often modified to reflect company standards.

Note: Quality turnkey systems are available from such companies as HiWire, PADS, PCAD, ORCAD, SmartWork, Maxi PC, SchemA, and others.

CAD Systems and Software
Unit 2

Assignment Sheet 1—Locate and Identify Parts of a CAD System

Name ____________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number of components located	______
Accuracy of performance data	______
Neatness and legibility	______

Directions: Examine the equipment that makes up a system or workstation as selected by your instructor. Document the critical information about each piece of equipment, including performance data.

CAD Alert: Take advantage of this assignment to practice inputting from the keyboard. Your work will look neater, you can save time, and you will have an opportunity to practice typing skills.

Example:

Printer
Name: Laserjet
Model: IV M
Manufacture: Hewlet Pakard
Size: 8 1/2 × 11
Speed: 12 pages per minute (ppm)
Input: parallel

1. Plotter
Name:
Model:
Manufacture:
Size:
Speed:
Input:

Assignment Sheet 1

2. Computer
   Name:
   Model:
   Manufacture:
   Size:
   Speed:
   Input:

3. Monitor
   Name:
   Model:
   Manufacture:
   Size:
   Speed:
   Input:

4. Mouse
   (if available)
   Name:
   Model:
   Manufacture:
   Size:
   Speed:
   Input:

5. Graphics tablet
   (if available)
   Name:
   Model:
   Manufacture:
   Size:
   Speed:
   Input:

6. Software
   DOS Version:
   Windows Version:
   CAD Software Name:
   CAD Manufacture:
   CAD Version:
   Memory Requirements:
   H.D. Requirements:
   Names of Available Libraries:

CAD Systems and Software
Unit 2

Assignment Sheet 2—Locate, Print, and Sketch Items From Symbol Libraries

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Library properly titled by name and version number	______
Symbols noted according to application	______
Symbols sketched or printed for presentation	______

Directions: Examine one or two symbol libraries designated by your instructor. Note where the symbols would have applications in electronic drafting, then print or sketch at least five selected symbols to show to your fellow students.

CAD Alert: Sketch a couple of symbols by hand, then print the rest of the symbols on a plotter. Note how much faster the CAD system works. Then, compare the quality.

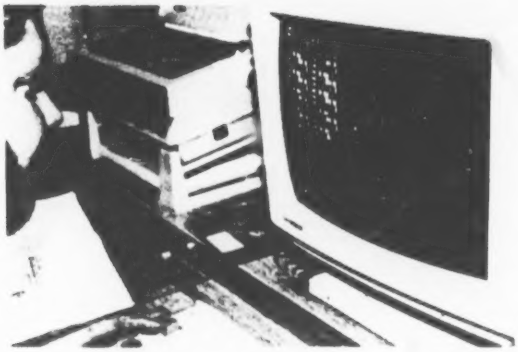
Title of Library 1:

Titles of selected symbols:

Title of Library 2:

Titles of selected symbols:

Note: Be sure to turn your sketches and symbol prints in to your instructor for evaluation.



Basic Electronic Theory
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to solve problems using Ohm's law and determine the resistance of series and parallel circuits. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to basic electronic theory with their correct definitions.
2. Solve problems related to elements of Ohm's law.
3. Complete statements about guidelines for expressing and using powers of ten.
4. Select true statements about applications of discrete devices and ICs.
5. Match IC families with their characteristics.
6. Match IC circuit families with abbreviations for their logic configurations.
7. Select true statements about typical digital and analog applications.
8. Identify types of basic types of circuits and their characteristics.
9. Write basic formulas for finding resistance in series and parallel circuits.
10. Solve problems using Ohm's law. (Assignment Sheet 1)
11. Determine the resistance of series and parallel circuits. (Assignment Sheet 2)

Basic Electronic Theory
Unit 3

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparencies as needed if you add instructional items to this unit.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.
11. Discuss and demonstrate the procedures in the job sheets, and obtain any special tools and materials required.

Basic IC Families
and Packages
Unit 5

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. A device used to increase an output signal

______b. A set of ICs that provide continuous control of a voltage or current

______c. A set of ICs that provide electronic logic control of a circuit

______d. A basic digital circuit

______e. A reference point for most voltage measurements; this point has a zero potential difference between it and earth

______f. Leadless ceramic chip carrier

______g. Six

______h. A high gain amplifier which is a basic class of analog ICs

______i. The type of container that houses an electronic chip

______j. The center-to-center distance between adjacent leads on a package

______k. Four

______l. Surface mount

______m. Surface mount device

______n. Surface mount technology

1. SM
2. Hex
3. Waveform
4. SMT
5. Amplifier
6. Timer
7. Digital IC families
8. V_{cc}
9. Quod
10. Analog IC families
11. Pitch
12. Op-Amp
13. Voltage regulator
14. LCC
15. Gate
16. SMD
17. Ground
18. Package

Written Test

______o. A class of analog ICs used to produce an output waveform at a specific time or interval

______p. DC supply voltage

______q. A class of analog ICs used to maintain a constant voltage

______r. Graphical representation of an electromagnetic wave

2. Match basic analog devices with their characteristics.

______a. May have a negative (–) or inverting input, or a positive (+) or noninverting input

______b. May have a negative (–) inverting input, or a positive (+) noninverting input

______c. May have three terminals or multi-terminals

______d. May be a duel in-line package with multi-terminals or a metal can package with multi-terminals

1. Voltage regulators
2. Operational amplifier
3. Timers
4. Current-differencing amplifier

3. Differentiate between package and schematic diagrams for analog devices. Place a "P" beside the definition of a package diagram and an "S" beside the definition of a schematic diagram.

______a. This diagram shows all pin connections and the power supply terminals V+ and V–.

______b. This diagram may not show the V+ and V– power supply terminals, and may not show all pin connections.

Written Test

4. Match analog devices with their characteristics. Place the number beside the analog device in the blank beside the description of its characteristics.

______a. Usually require two power supply terminals, V+ and V−

______b. May require magnetic shielding and should normally be kept as short as possible

______c. May vary from very small input levels to very large output signal levels, and may require special handling techniques

______d. Requirements such as shielding, ground plaines, and lead separation are as specified by engineering

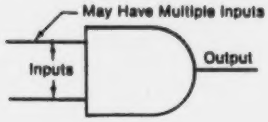
1. Signal levels
2. Operational amplifiers
3. Input leads
4. Special circuit requirements

5. Complete statements about information found in analog reference materials. Circle the information that best completes each of the following statements.

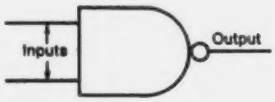
   a. Reference materials list pin numbers for numbering sequence and package configurations for (**lead connections**) (**ground pins**).

   b. Electrical specifications for voltage and (**resistance**) (**current**) also appear in reference materials.

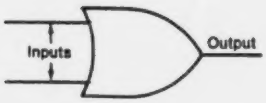
6. Identify digital gate and device symbols. Place the number beside the symbol name in the blank below its illustration.



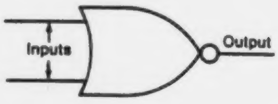
a. ____________



b. ____________



c. ____________

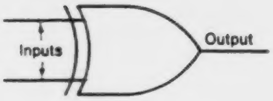


d. ____________

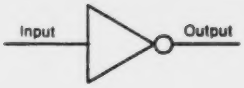
1. NOR gate
2. JK Flip Flop
3. Inverter
4. AND gate

Written Test

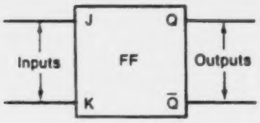
5. Exclusive-OR gate
6. Monostable multivibrator
7. NAND gate
8. OR gate



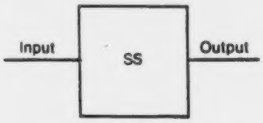
e. ______________



f. ______________



g. ______________



h. ______________

7. Differentiate between package diagrams and schematic diagrams for digital devices. Place a "P" beside the definition of a package diagram and an "S" beside the definition of a schematic diagram.

______a. This diagram shows all pin connections, and may show multiple circuits.

______b. This diagram shows the number of gates in the same IC package.

8. Select true statements about digital devices and their design. Place an "X" beside each true statement.

______a. Digital devices seldom contain multiple gates in the IC package.

______b. When one gate is specified in a schematic drawing, that gate only may be used.

______c. Digital ICs normally have one power supply connection, V_{cc}, and one ground connection, GND, which are used for all the gates on the IC.

______d. ICs normally require a minimum space of one square inch on a printed circuit board.

______e. ICs with the same types of gates should be grouped together on a printed circuit board.

Written Test

9. Complete statements about gate package equivalent functions. Circle the material that best completes each of the following statements.

   a. Gate package equivalent means that individual gates of the same type may be interchanged with each other without changing the (**logic**) (**physical size**) of the circuit.

   b. Gate package equivalent also means that gates may be (**substituted**) (**interchanged**) to aid in PC layout.

   c. Gate package equivalent also means gates may be combined, but this must always be verified with (**a design engineer**) (**the head drafter**).

10. Complete statements about pin locations for both analog and digital ICs. Circle the material that best completes each of the following statements.

    a. Pin locations on a schematic are arranged to maintain neatness and (**convenience**) (**accuracy**) of the drawing.

    b. Pin representation as shown on a schematic diagram (**will never vary**) (**may vary**) from the pin locations on the actual chip.

    c. On an actual IC, pins are placed for the purpose of maintaining (**even pin numbers on the right**) (**indexing continuity**).

    d. Because of the variations between schematic and actual application, always refer to appropriate reference material for pin location on (**a schematic**) (**the actual chip**) when you are laying out an IC.

11. Select true statements about information found in digital reference materials. Place an "X" beside each true statement.

    ______a. For digital applications, references include the pin numbers for numbering sequence.

    ______b. Digital reference materials also include gates per package and package configurations for lead connections.

    ______c. Electrical specifications also appear in digital reference materials.

Written Test

12. Complete statements about IC technology and its applications. Circle the information that best completes each of the following statements.

    a. Integration is the technology of concentrating (**ten**) (**two**) or more semiconductors on a single integrated circuit.

    b. Because IC technology deals in small to extremely large numbers, a reference system has been developed to identify (**types**) (**degrees**) of integration.

    c. **SSI** or small scale integration means there are up to (**10**) (**100**) semiconductor devices on a single IC.

    d. **MSI** or medium scale integration means there are up to (**ten thousand**) (**a thousand**) semiconductor devices on a single IC.

    e. **LSI** or large scale integration means there are (**several**) (**five**) thousand semiconductor devices on a single IC.

    f. **VLSI** or very large scale integration means there are (**many thousands of**) (**five hundred thousand**) semiconductor devices on a single IC.

13. Complete statements about surface mounted technology. Circle the material that best completes each of the following statements.

    a. Surface mounted technology is the answer to the continuing drive of the electronics industry to develop (**smaller**) (**faster**) devices with greater performance at a lower cost.

    b. Surface mounted devices typically have a lower profile than a DIP, are (**smaller**) (**only slightly larger**) than a DIP, and take up less real estate on a printed circuit board.

    c. Surface mounted devices are easily handled by (**hand assembly personnel**) (**automated assembly equipment**).

    d. Surface mounted technology allows the IC manufacturer to create devices with a larger number of leads available in (**a relatively small**) (**an extremely small**) package.

Written Test

14. Match common IC package types with their uses. Place the number beside the package type in the blank beside the description of its use.

______a. Often used in design prototypes because of their large physical size makes them easy to handle and work with.

______b. Used to replace the dual in-line package with surface-mounted technology to save space on a printed circuit board.

______c. Used to accommodate complex integrated circuits such as microprocessors with a large number of leads that require replacement without soldering to the printed circuit board.

______d. Used in applications where a great number of pins, often a hundred or more, are required, and the CLCC may be soldered directly on a printed circuit board.

______e. Used in applications like CLCCs, but the QFP is plastic, not ceramic, and has to be used where plastic will meet specifications.

1. PLCC
2. DIP
3. QFP
4. CLCC
5. SO

***Permission to duplicate this test is granted.**

Basic IC Families and Packages
Unit 5

Unit Evaluation Form

Student Name ______________________________ Unit Rating ____________

Assignment Sheet 1—Draw Schematic Symbols for Analog and Digital ICs Rating ______

Comments: ____

____

Assignment Sheet 2—Number Pins on IC Packages Rating ______

Comments: ____

____

Assignment Sheet 3—Sketch Analog Symbols and IC Packages Rating ______

Comments: ____

____

Assignment Sheet 4—Sketch Digital Symbols and IC Packages Rating ______

Comments: ____

____

Assignment Sheet 5—Sketch Schematic Symbols and Create Truth Tables for Logic Gates Rating ______

Comments: ____

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

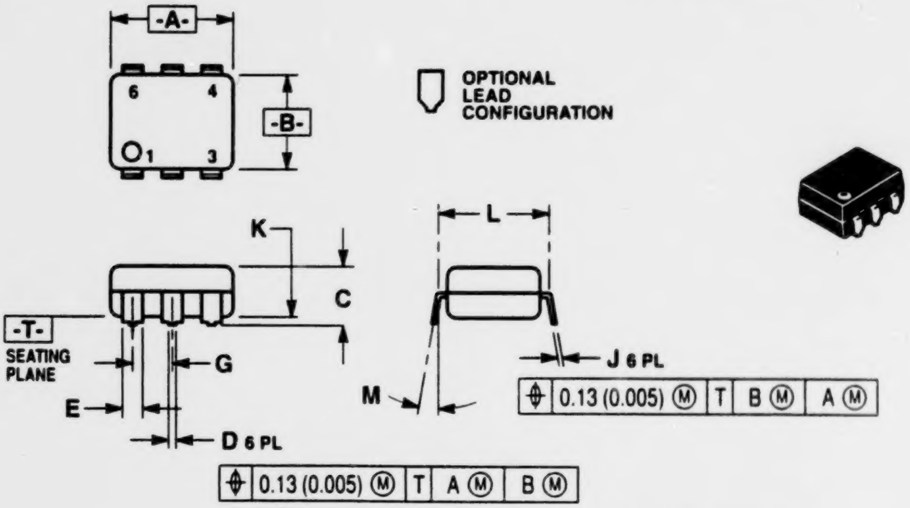
Teacher Signature ______________________________ Date ____________

Student Signature ______________________________ Date ____________

°Permission to duplicate this form is granted.

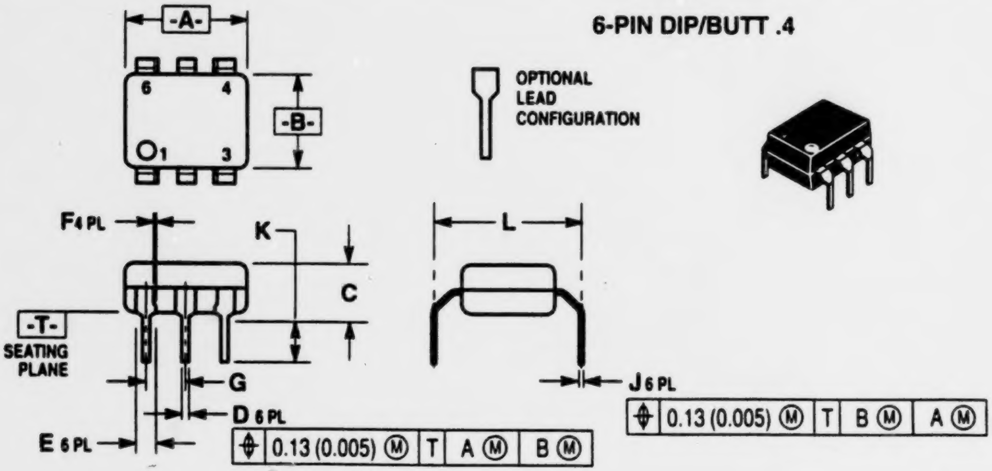
DIP (Dual In-Line Package) IC

6-PIN DIP/BUTT .3


-A-
6
4
1
3
-B-
OPTIONAL
LEAD
CONFIGURATION
K
C
L
-T-
SEATING
PLANE
G
E
D 6 PL
M
J 6 PL
⌖ 0.13 (0.005) Ⓜ T B Ⓜ A Ⓜ
⌖ 0.13 (0.005) Ⓜ T A Ⓜ B Ⓜ

CASE 730B-02

6-PIN DIP/BUTT .4


-A-
6
4
1
3
-B-
OPTIONAL
LEAD
CONFIGURATION
F 4 PL
K
C
L
-T-
SEATING
PLANE
G
D 6 PL
E 6 PL
J 6 PL
⌖ 0.13 (0.005) Ⓜ T A Ⓜ B Ⓜ
⌖ 0.13 (0.005) Ⓜ T B Ⓜ A Ⓜ

CASE 730D-03

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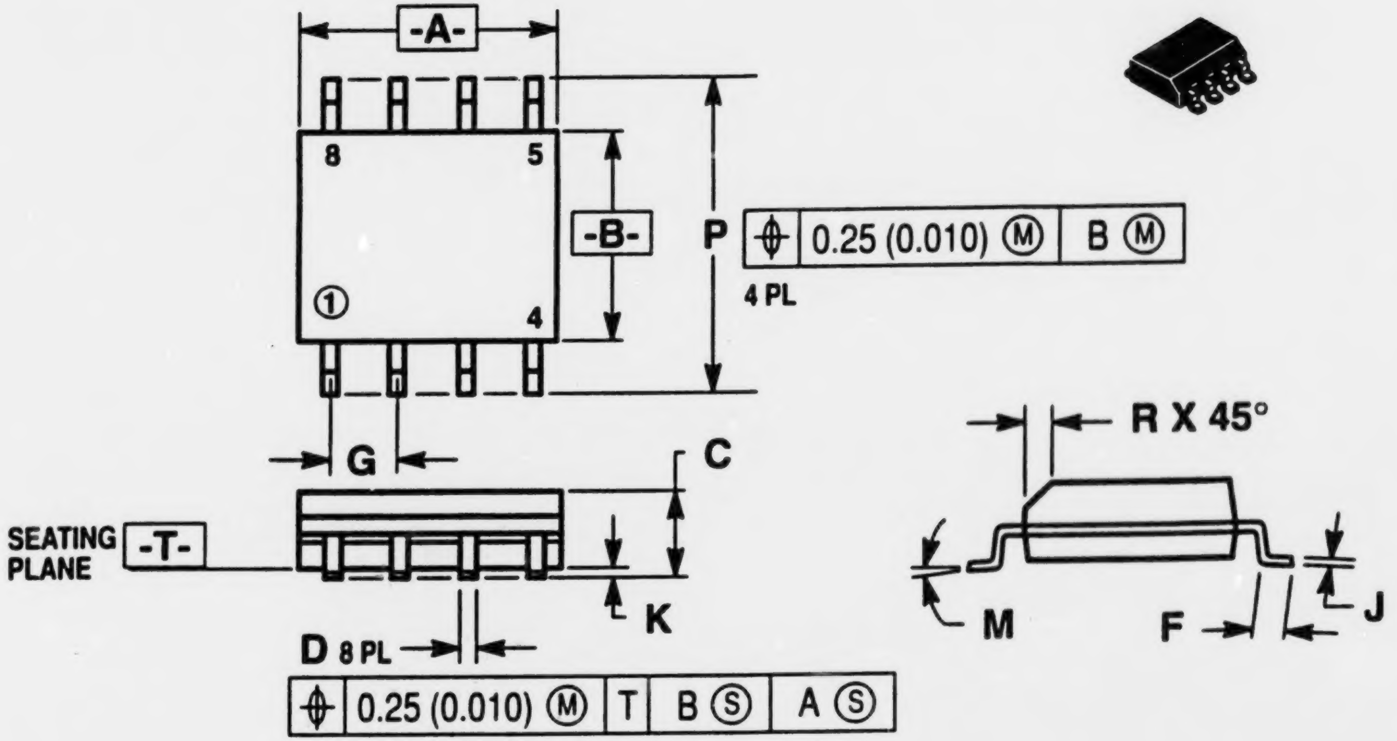
SO (Small Outlined) IC


-A-
8
5
①
4
-B-
P
0.25 (0.010) Ⓜ B Ⓜ
4 PL
G
C
SEATING PLANE
-T-
K
D 8 PL
0.25 (0.010) Ⓜ T B Ⓢ A Ⓢ
R X 45°
M
F
J

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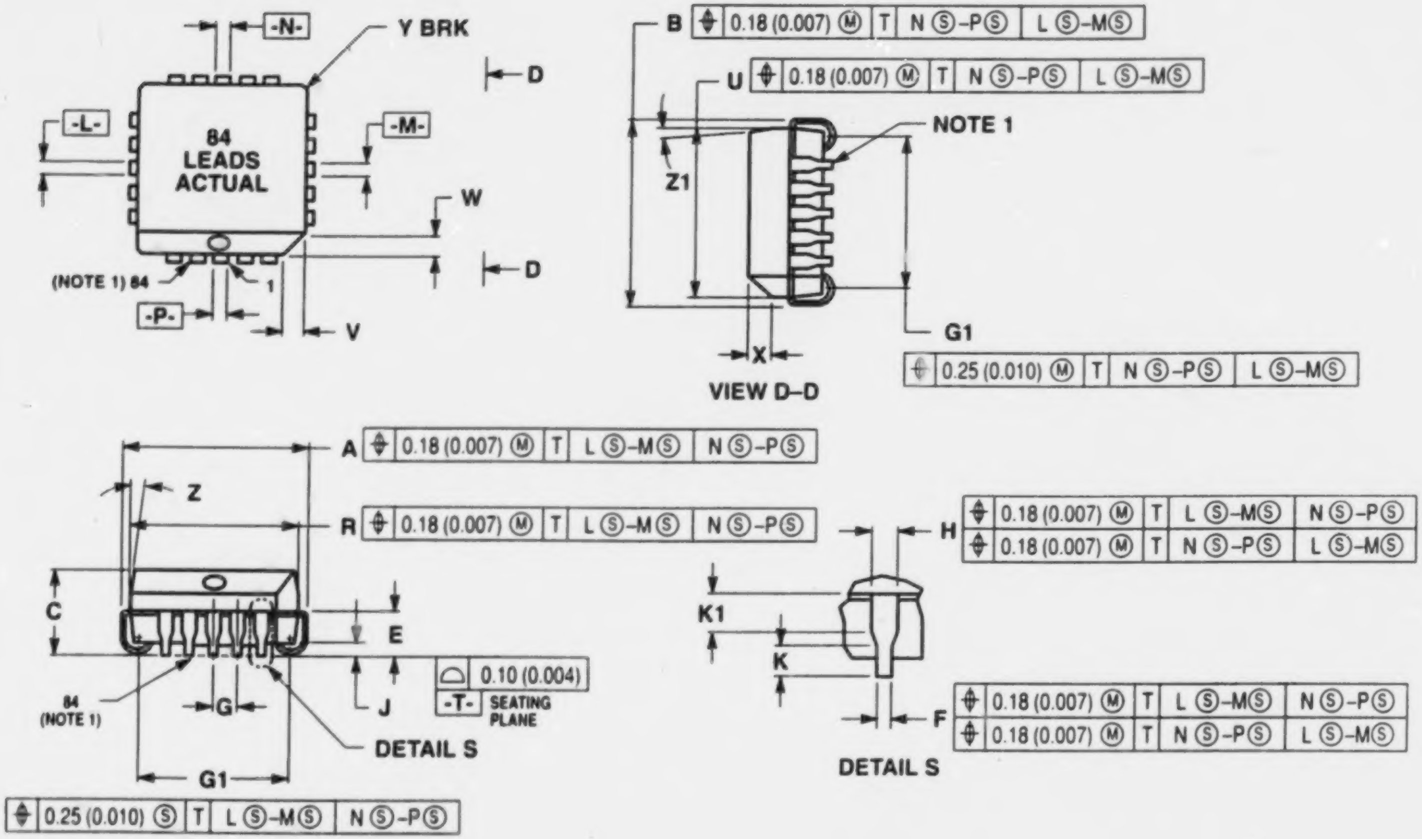
PC Board Layout and Electronic Drafting With CAD, Unit 5
Teacher Page 25

PLCC (Plastic Leaded Chip Carrier) IC


-N-
Y BRK
D
-L-
84
LEADS
ACTUAL
-M-
W
D
(NOTE 1) 84
1
-P-
V
B ⌖ 0.18 (0.007) Ⓜ T N Ⓢ–P Ⓢ L Ⓢ–M Ⓢ
U ⌖ 0.18 (0.007) Ⓜ T N Ⓢ–P Ⓢ L Ⓢ–M Ⓢ
NOTE 1
Z1
G1
X
VIEW D–D
⌖ 0.25 (0.010) Ⓜ T N Ⓢ–P Ⓢ L Ⓢ–M Ⓢ
A ⌖ 0.18 (0.007) Ⓜ T L Ⓢ–M Ⓢ N Ⓢ–P Ⓢ
Z
R ⌖ 0.18 (0.007) Ⓜ T L Ⓢ–M Ⓢ N Ⓢ–P Ⓢ
C
E
0.10 (0.004)
-T- SEATING PLANE
J
84
(NOTE 1)
G
DETAIL S
G1
⌖ 0.25 (0.010) Ⓢ T L Ⓢ–M Ⓢ N Ⓢ–P Ⓢ
H ⌖ 0.18 (0.007) Ⓜ T L Ⓢ–M Ⓢ N Ⓢ–P Ⓢ
⌖ 0.18 (0.007) Ⓜ T N Ⓢ–P Ⓢ L Ⓢ–M Ⓢ
K1
K
F ⌖ 0.18 (0.007) Ⓜ T L Ⓢ–M Ⓢ N Ⓢ–P Ⓢ
⌖ 0.18 (0.007) Ⓜ T N Ⓢ–P Ⓢ L Ⓢ–M Ⓢ
DETAIL S

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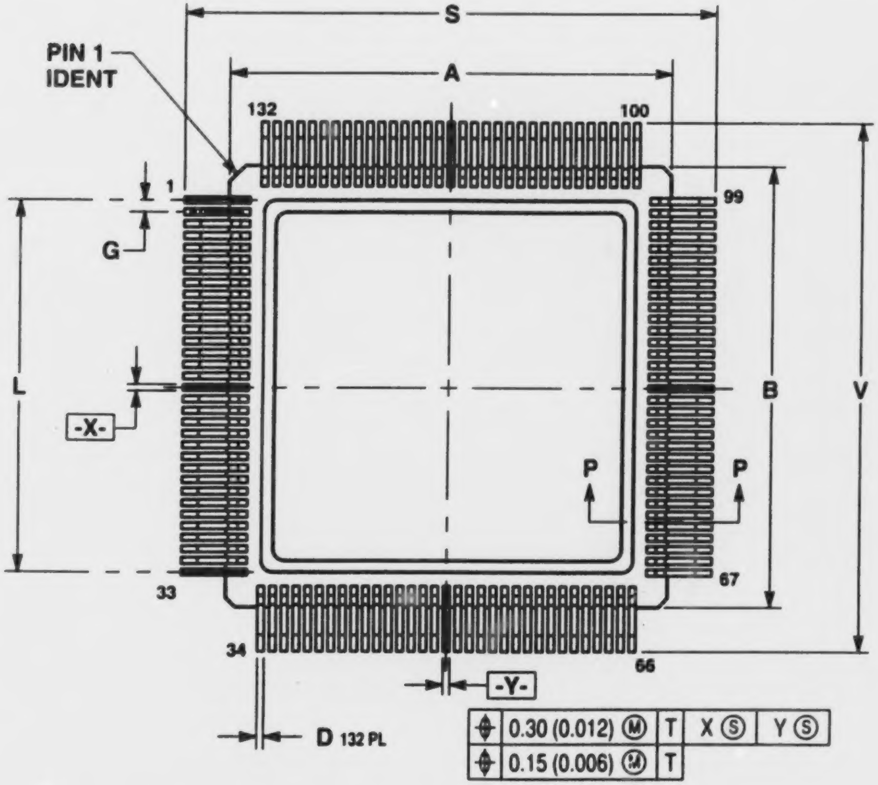
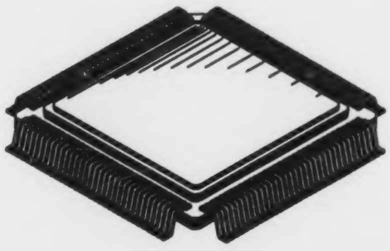
PC Board Layout and Electronic Drafting With CAD, Unit 5
Teacher Page 27

TM 3

CLCC (Ceramic Leaded Chip Carrier) IC

CLCC-132


S
A
PIN 1 IDENT
132
100
1
99
G
L
-X-
B
V
P
P
67
33
34
66
-Y-
D 132 PL
0.30 (0.012) Ⓜ T X Ⓢ Y Ⓢ
0.15 (0.006) Ⓜ T



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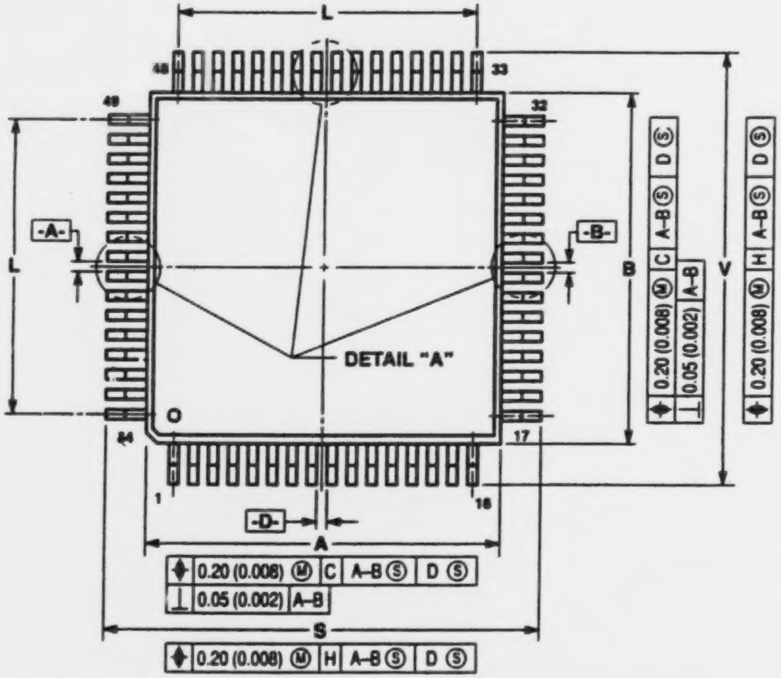
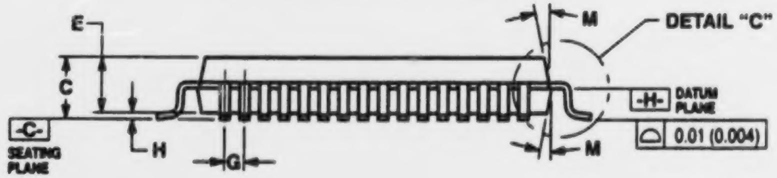
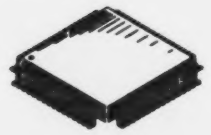
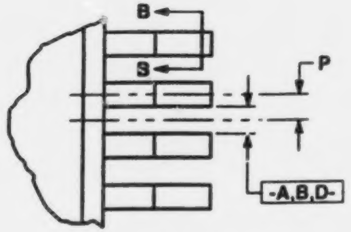
QFP (Quad Flat Pack) IC

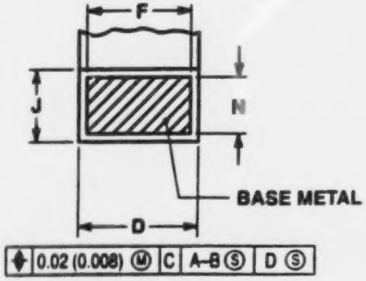

L
48
33
49
32
-A-
-B-
L
B
V
DETAIL "A"
O
64
17
1
16
-D-
A
0.20 (0.008) Ⓜ C A–B Ⓢ D Ⓢ
0.05 (0.002) A–B
S
0.20 (0.008) Ⓜ H A–B Ⓢ D Ⓢ


E
C
-C-
SEATING PLANE
H
G
M
DETAIL "C"
-H- DATUM PLANE
0.01 (0.004)
M





DETAIL "A"


F
J
N
BASE METAL
D
0.02 (0.008) Ⓜ C A–B Ⓢ D Ⓢ

SECTION B–B

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Basic IC Families
and Packages
Unit 5

Information Sheet

1. **Terms and definitions**

   a. **Amplifier** — A device used to increase an output signal

   b. **Analog IC families** — A set of ICs that provide continuous control of a voltage or current

   c. **Digital IC families** — A set of ICs that provide electronic logic control of a circuit

   d. **Gate** — A basic digital circuit

   e. **Ground** — A reference point for most voltage measurements; this point has a zero potential difference between it and earth

   f. **Hex** — Six

   g. **LCC** — Leadless ceramic chip carrier

   h. **OP-Amp (operational amplifier)** — A high gain amplifier which is a basic class of analog ICs

   i. **Package** — The type of container that houses an electronic chip

   j. **Pitch** — The center-to-center distance between adjacent leads on a package

   k. **Quod** — Four

   l. **SM** — Surface mount

   m. **SMD** — Surface mount device

   n. **SMT** — Surface mount technology

   o. **Timer** — A class of analog ICs used to produce an output waveform at a specific time or interval

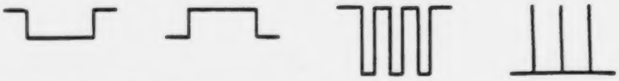
   p. V_{cc} – DC supply voltage

   q. **Voltage regulator** — A class of analog ICs used to maintain a constant voltage

Information Sheet

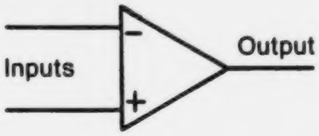
r. **Waveform** — Graphical representation of an electromagnetic wave

Examples:

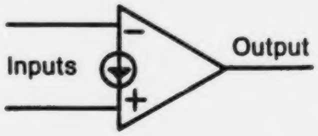


2. **Basic analog devices and their characteristics**

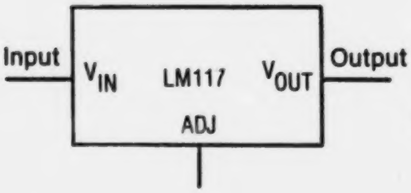
a. **Operational amplifier** — May have a negative (–) or inverting input, or a positive (+) or noninverting input


–
+
Inputs
Output

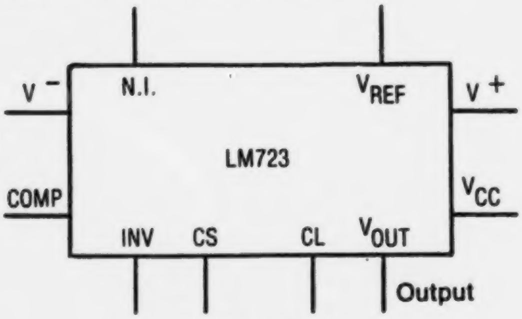
b. **Current-differencing amplifier** — May have a negative (–) inverting input, or a positive (+) noninverting input


–
+
Inputs
Output

c. **Voltage regulators** — May have three terminals or multi-terminals


Input
V_{IN}
LM117
V_{OUT}
Output
ADJ

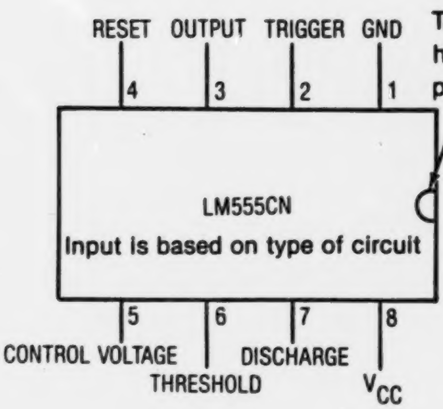
Three terminal

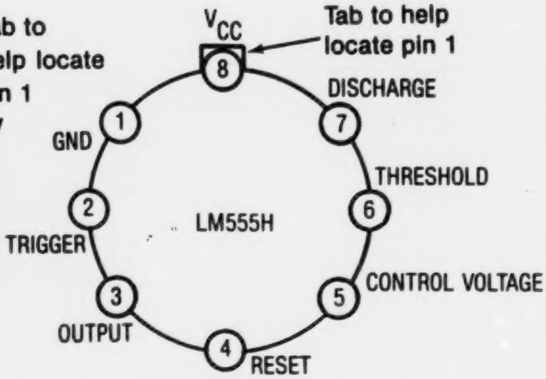

V^-
N.I.
V_{REF}
V^+
LM723
COMP
V_{CC}
INV
CS
CL
V_{OUT}
Output

Multi-terminal

Information Sheet

d. **Timers** — May be a duel in-line package with multi-terminals or a metal can package with multi-terminals


RESET
OUTPUT
TRIGGER
GND
4
3
2
1
Tab to help locate pin 1
LM555CN
Input is based on type of circuit
5
6
7
8
CONTROL VOLTAGE
THRESHOLD
DISCHARGE
V_{CC}

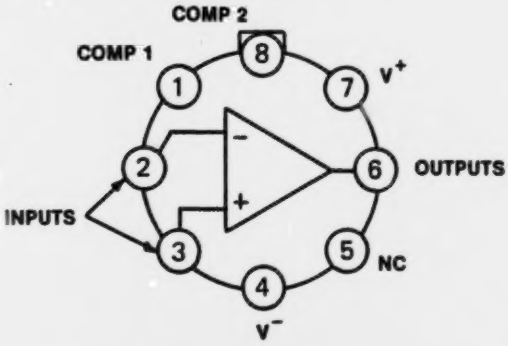

V_{CC}
Tab to help locate pin 1
8
DISCHARGE
7
GND
1
THRESHOLD
6
2
LM555H
TRIGGER
3
5
CONTROL VOLTAGE
OUTPUT
4
RESET

DIP

Metal can package

3. Package and schematic diagrams for analog devices

a. A package connection diagram shows all pin connections and the power supply terminals V+ and V–.

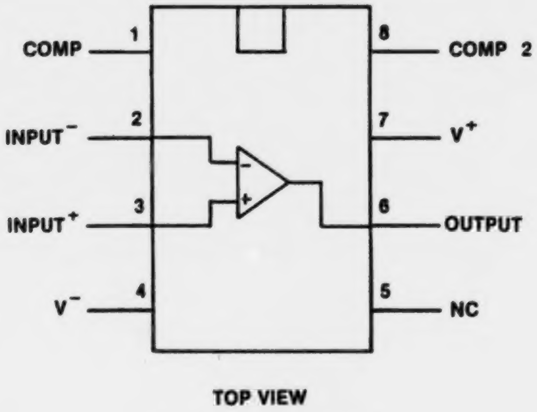

COMP 2
COMP 1
8
1
7
V+
2
6
OUTPUTS
INPUTS
3
5
NC
4
V−

NOTE: Pin 4 connected to case.

Metal can package

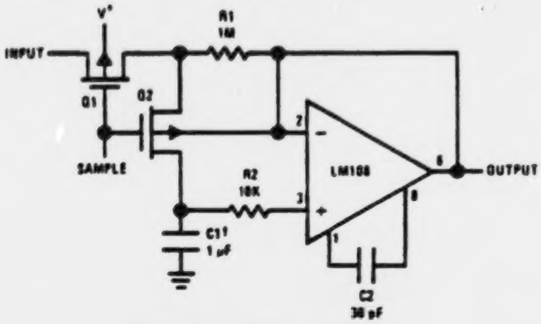
Information Sheet

b. A package connection may contain multiple circuits.


COMP
1
INPUT⁻
2
INPUT⁺
3
V⁻
4
8
COMP 2
7
V⁺
6
OUTPUT
5
NC
TOP VIEW

Dual in-line package

c. A schematic diagram for an analog device may not show the V+ and V− power supply terminals, and may not show all pin connections.


V⁺
R1
1M
INPUT
Q1
Q2
SAMPLE
R2
10K
C1
1 µF
2
3
LM108
6
8
1
OUTPUT
C2
30 pF

Fast summing amplifier

4. **Analog devices and their characteristics**

   a. **Operational amplifiers** — Usually require two power supply terminals, V+ and V−

   b. **Input leads** — May require magnetic shielding and should normally be kept as short as possible

   c. **Signal levels** — May vary from very small input levels to very large output signal levels, and may require special handling techniques

   d. **Special circuit requirements** — Requirements such as shielding, ground plaines, and lead separation are as specified by engineering

Information Sheet

5. **Information found in analog reference materials**

   a. Reference materials list pin numbers for numbering sequence and package configurations for lead connections.

   b. Electrical specifications for voltage and current also appear in reference materials.

   Note: Reference materials are available from manufacturers or wholesalers for major IC producers such as National, Motorola, Texas Instruments, and many others.

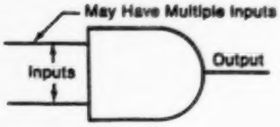
6. **Digital gate and device symbols**

   a. The basic digital gates are the AND, NAND, OR, NOR, Exclusive OR, and Inverter.

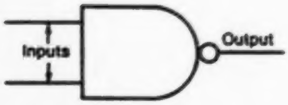
   b. The number of inputs into a gate may vary, and symbols are not shown with their input/output leads.

   Note: For better visualization, leads are shown in the following illustrations.

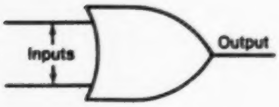
   (1) **AND gate—**



   (2) **NAND gate—**

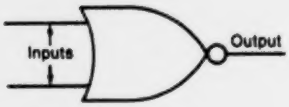


   (3) **OR gate—**

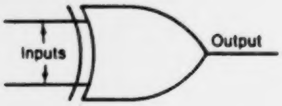


Information Sheet

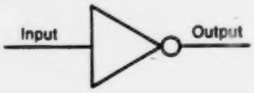
(4) **NOR gate—**


Inputs
Output

(5) **Exclusive-OR gate—**

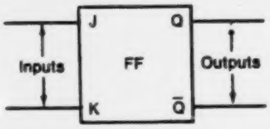

Inputs
Output

(6) **Inverter gate—**

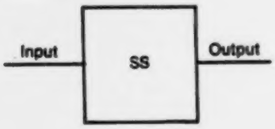

Input
Output

c. Other digital devices include the JK Flip Flop and the monostable multivibrator.

(1) **JK Flip Flop—**


J
Q
Inputs
FF
Outputs
K
Q̄

(2) **Monostable multivibrator—**

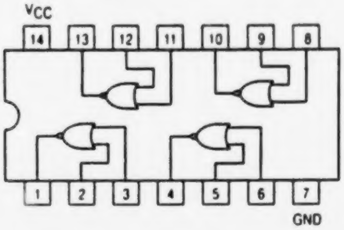

Input
SS
Output

Information Sheet

7. Package and schematic diagrams for digital devices

a. A digital package connection diagram shows all pin connections, and may show multiple circuits.

Digital **NOR** gate


VCC
14
13
12
11
10
9
8
1
2
3
4
5
6
7
GND

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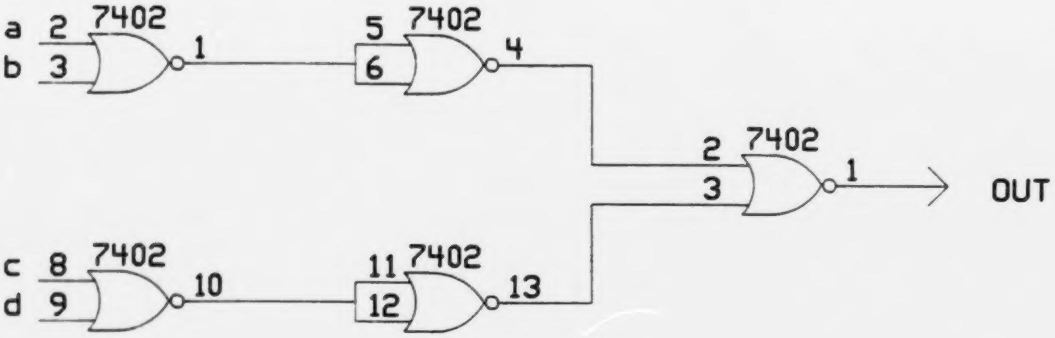
b. A digital schematic diagram shows the number of gates in the same IC package, and may include a truth table to verify logic.


a
b
2
3
7402
1
5
6
7402
4
2
3
7402
1
OUT
c
d
8
9
7402
10
11
12
7402
13

4 - INPUT NOR GATE

TRUTH TABLE

A	B	C	D	OUT
L	L	L	L	H
X	X	X	X	L

Information Sheet

8. Digital devices and their design

a. Digital devices often contain multiple gates in the IC package.

b. When one gate is specified in a schematic drawing, any gate within the IC may be used.

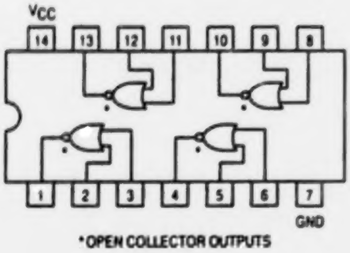
c. Digital ICs normally have one power supply connection, V_{cc}, and one ground connection, GND, which are used for all the gates on the IC.

d. ICs with the same types of gates should be grouped together on a printed circuit board.

9. Gate package equivalent functions

a. Gate package equivalent means that individual gates of the same type may be interchanged with each other without changing the logic of the circuit.

Package connection diagram for quad NOR gates



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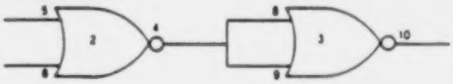
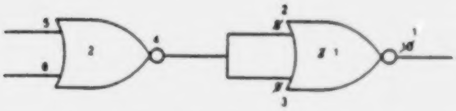
Information Sheet

b. Gate package equivalent also means that gates may be interchanged to aid in PC layout.

Note: In the following graphic, the 1 gate has been interchanged with the 3 gate to aid in PC layout.



Logic diagram from schematic



Interchange of gates to improve PC layout

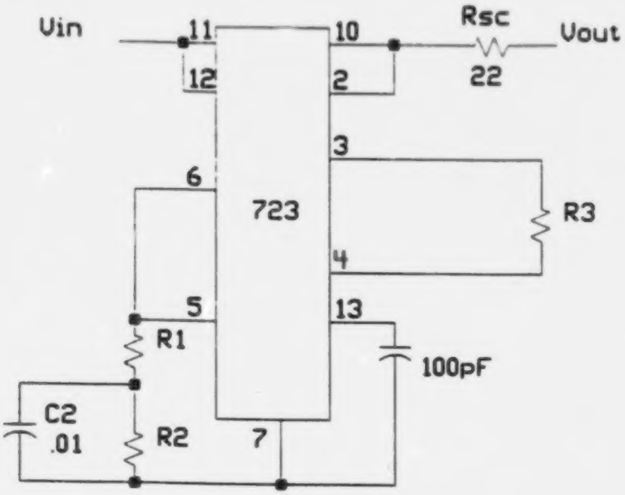
c. Gate package equivalent also means gates may be combined, but this must always be verified with a design engineer.

10. Pin locations for both analog and digital ICs

a. Pin locations on a schematic are arranged to maintain neatness and convenience of the drawing.

b. Pin representation as shown on a schematic diagram may vary from the pin locations on the actual chip.

Note: In the following schematic, notice that pins 12 and 6 are located next to each other.

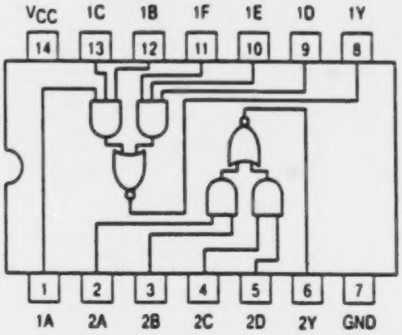


Information Sheet

c. On an actual IC, pins are placed for the purpose of maintaining indexing continuity.

Note: In the following drawing of an actual IC, pins 12 and 6 are on opposite sides of the IC, but pin numbers correspond.

CONNECTION DIAGRAM



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d. Because of the variations between schematic and actual application, always refer to appropriate reference material for pin location on the actual chip when you are laying out an IC.

11. Information found in digital reference materials

a. For digital applications, references include the pin numbers for numbering sequence.

b. Digital reference materials also include gates per package and package configurations for lead connections.

c. Electrical specifications also appear in digital reference materials.

Note: Reference materials are available from manufacturers or wholesalers for major IC producers such as National, Motorola, Allegro, Texas Instruments, and many others.

12. IC technology and its applications

a. Integration is the technology of concentrating two or more semiconductors on a single integrated circuit.

b. Because IC technology deals in small to extremely large numbers, a reference system has been developed to identify ICs by degrees of integration.

Information Sheet

c. **SSI** or small scale integration means there are up to 10 semiconductor devices on a single IC.

d. **MSI** or medium scale integration means there are up to a thousand semiconductor devices on a single IC.

e. **LSI** or large scale integration means there are several thousand semiconductor devices on a single IC.

f. **VLSI** or very large scale integration means there are many thousands of semiconductor devices on a single IC.

13. Surface mounted technology

a. Surface mounted technology is the answer to the continuing drive of the electronics industry to develop smaller devices with greater performance at a lower cost.

b. Surface mounted devices typically have a lower profile than a DIP, are smaller than a DIP, and take up less real estate on a printed circuit board.

c. Surface mounted devices are easily handled by automated assembly equipment.

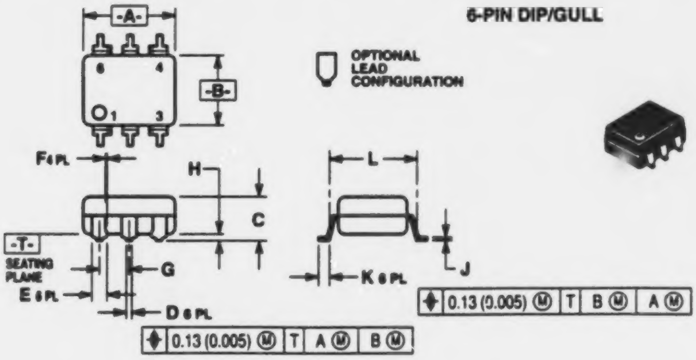
d. Surface mounted technology allows the IC manufacturer to create devices with a larger number of leads available in an extremely small package.

Note: SM technology is a good example of industrial miniaturization.

14. Common IC package types and their uses

a. **DIP (dual in-line packages)** — Often used in design prototypes because their large physical size makes them easy to handle and work with

6-PIN DIP/GULL



CASE 730C-03

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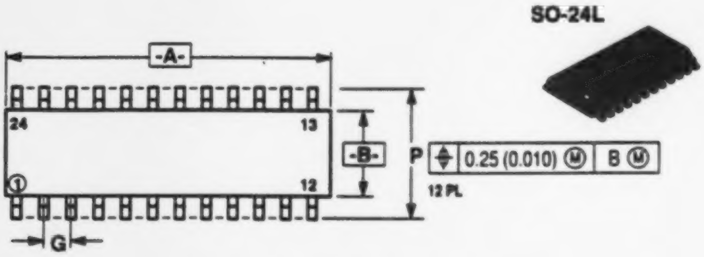
Information Sheet

b. **SO (small outlined IC packages)** — Used to replace the dual in-line package with surface-mounted technology to save space on a printed circuit board


SO-24L
-A-
24
13
1
12
-B-
P
0.25 (0.010) Ⓜ B Ⓜ
12 PL
G

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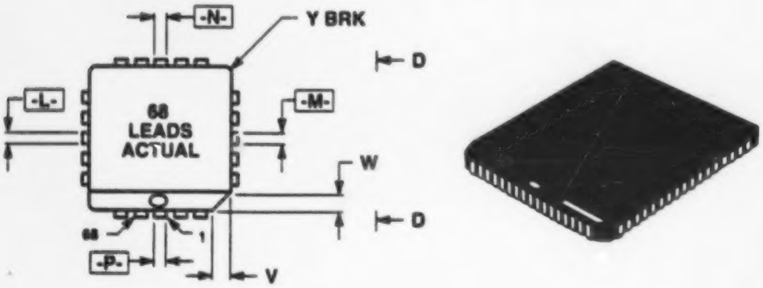
c. **PLCC (plastic leaded chip carrier ICs)** — Used to accommodate complex integrated circuits such as microprocessors with a large number of leads that require replacement without soldering to the printed circuit board


-N-
Y BRK
D
-L-
-M-
68
LEADS
ACTUAL
W
D
68
1
-P-
V

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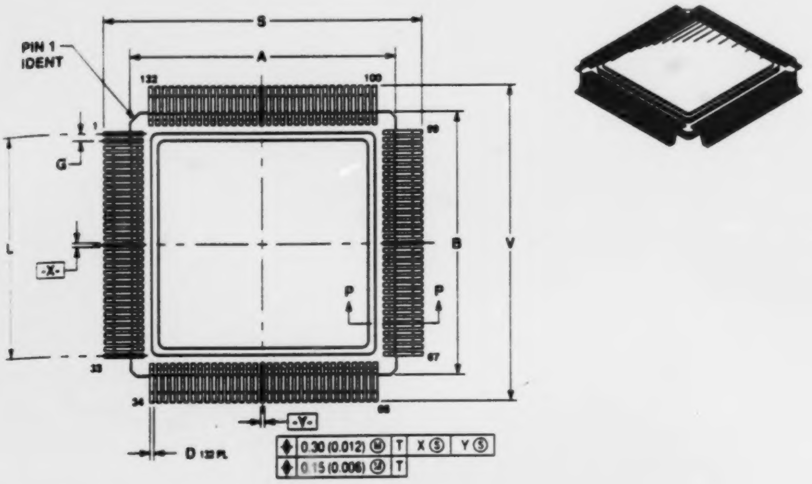
Information Sheet

d. **CLCC (ceramic leaded chip carrier ICs)** — Used in applications where a great number of pins, often a hundred or more, are required, and the CLCC may be soldered directly onto a printed circuit board

CLCC-132


S
A
PIN 1 IDENT
132
100
99
1
G
L
-X-
B
V
P
P
33
67
34
66
-Y-
D 132 PL
0.30 (0.012) Ⓜ T X Ⓢ Y Ⓢ
0.15 (0.006) Ⓜ T

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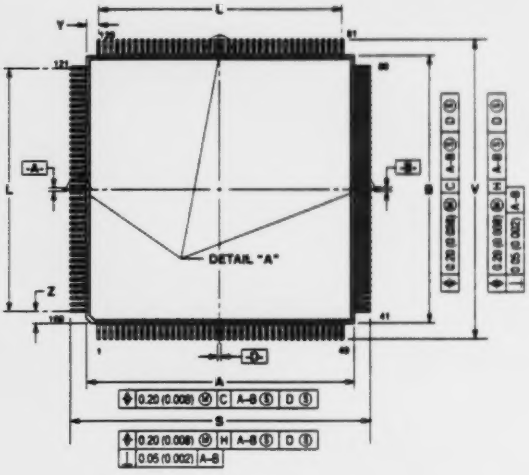
e. **QFP (quad flat pack ICs)** — Used in applications like CLCCs, but the QFP is plastic, not ceramic, and has to be used where plastic will meet specifications


L
Y
81
121
80
-A-
-B-
L
B
V
DETAIL "A"
Z
41
1
40
-D-
A
0.20 (0.008) Ⓜ C A-B Ⓢ D Ⓢ
S
0.20 (0.008) Ⓜ H A-B Ⓢ D Ⓢ
0.05 (0.002) A-B

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Basic IC Families
and Packages
Unit 5

Assignment Sheet 1—Draw Schematic Symbols for Analog and Digital ICs

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number of drawings attempted	______
Number of drawings correctly presented	______
Neatness of drawing and legibility of lettering	______

Directions: Select appropriate templates, or use a CAD system, and draw the symbols for the devices listed below. Designate input and output where appropriate.

CAD Alert: If you are using a CAD system with a component library, copy the symbols from the library to save yourself valuable time.

Problems:

A. Analog devices:

1. Operational amplifier

2. Current-differencing amplifier

3. Three terminal voltage regulator

Assignment Sheet 1

4. Timer, DIP 8-pin package

B. Digital devices:

1. AND gate, two inputs

2. NAND gate, two inputs

3. OR gate, two inputs

4. NOR gate, two inputs

5. Exclusive-OR gate, two inputs

6. Inverter gate, one input

Assignment Sheet 1

7. JK Flip Flop, two inputs

8. Monostable multivibrator, one input

Basic IC Families
and Packages
Unit 5

Assignment Sheet 2—Number Pins on IC Packages

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Pins 1 properly located	______
All pins numbered and labeled	______
Neatness of finished work	______

Directions: Use information from this unit or appropriate reference materials to number and label the IC packages that follow. Locate pin 1 on each package, then number and label all pins including the logic diagrams. Use a CAD system to print each from a library.

CAD Alert: Even when you're taking symbols from a CAD library, develop the good habit of checking the symbols against a data book to make sure there are no errors.

Problems:

A. 74HC10
Triple 3-Input NAND Gate

B. 74HHC27
Triple 3-Input NOR Gate

Assignment Sheet 2

C. 74HC86
Quad 2-Input Exclusive OR Gate

D. 74HC133
13-Input NAND Gate

E. 74HC386
Quad 2-Input Exclusive OR Gate

Basic IC Families
and Packages
Unit 5

Assignment Sheet 3—Sketch Analog Symbols and IC Packages

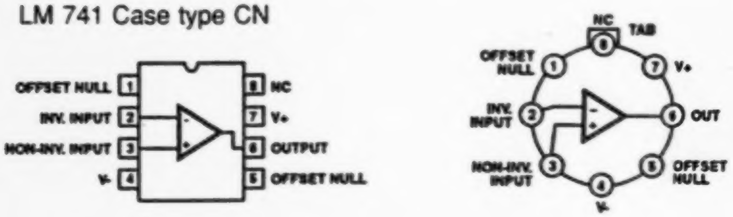
Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number of properly sketched symbols	______
Number of properly sketched packages	______
Pin numbers properly noted on packages	______

Directions: Use reference materials to look up the items listed in the problems. Sketch the case type of the IC, complete with part number and pin numbers, and then sketch the symbol.

Problems:

Example: LM 741 Case type CN


OFFSET NULL
1
INV. INPUT
2
NON-INV. INPUT
3
V-
4
8
NC
7
V+
6
OUTPUT
5
OFFSET NULL
-
+
NC
TAB
8
OFFSET NULL
1
7
V+
INV. INPUT
2
6
OUT
NON-INV. INPUT
3
5
OFFSET NULL
4
V-

Courtesy Harris Semiconductor. All rights reserved.

A. LM 337 Case type TO-220

B. LM 741 Case type H

Assignment Sheet 3

C. HA 2556

Basic IC Families and Packages
Unit 5

Assignment Sheet 4—Sketch Digital Symbols and IC Packages

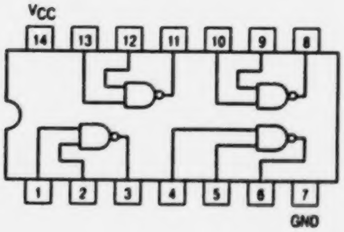
Name ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number of properly sketched symbols	______
Number of properly sketched packages	______
Pin numbers properly noted on packages	______

Directions: Use reference materials to look up the items listed in the problems. Sketch the case type of the IC, complete with part number and pin numbers, and then sketch the symbol.

CAD Alert: Remember that information on most of the components listed in this assignment sheet can probably be obtained in a CAD system library.

Example: MC74F00 Case type J



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Assignment Sheet 4

Problems:

A. MC74F04 Case type J

B. MC74F10 Case type J

C. MC74F112 Case type J

D. SN54LS136 Case type FK

Basic IC Families
and Packages
Unit 5

Assignment Sheet 5—Sketch Schematic Symbols and Create Truth Tables for Basic Logic Gates

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number schematic symbols properly sketched	______
Number of truth tables properly completed	______

Directions: Sketch the schematic symbols with inputs, and then create truth tables for each type of IC listed below. Use material from the information sheet or reference material for the information you need.

Problems:

A. SN74HC20

B. 74LS00

C. 74S04

D. 74S32

Logic, Schematic, and Other Diagrams
Unit 6

Objective Sheet

Unit Objective

After completing this unit, the student should be able to redraw an existing schematic, sketch a schematic on grid paper, draw a schematic, draw a harness layout, and draw a block diagram. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to logic, schematic, and other diagrams with their correct definitions.
2. Complete statements about block diagrams and their applications.
3. Select true statements about guidelines for drawing block diagrams.
4. Select true statements about logic diagrams and their applications.
5. Complete statements about guidelines for drawing logic diagrams.
6. Match logic diagram abbreviations with their meanings.
7. Match types of schematic drawings with their applications.
8. Complete statements about what schematics do.
9. Complete statements about guidelines for drawing schematics.
10. Select true statements about guidelines for applying schematic line conventions.
11. List methods of stage designation for circuits on schematics.

Objective Sheet

12. Match special symbols with their meanings.
13. Select true statements about the purposes of notes on schematics.
14. Complete statements about elements in a wire list.
15. List types of cables and cable connectors.
16. Complete statements about elements in cable assembly drawings.
17. Match harness terms with their definitions.
18. Select true statements about components of a harness.
19. Complete statements about elements in harness assembly drawings.
20. Match wiring termination abbreviations with their symbols.
21. Redraw an existing schematic. (Assignment Sheet 1)
22. Sketch a schematic on grid paper. (Assignment Sheet 2)
23. Draw a schematic. (Assignment Sheet 3)
24. Draw a harness layout. (Assignment Sheet 4)
25. Draw a block diagram. (Assignment Sheet 5)

Logic, Schematic, and Other Diagrams
Unit 6

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies as needed if you add instructional items to this unit.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

Suggested Activities

13. Give written test.
14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets.
15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. If you have an electronics manufacturing firm in your area, have an engineer from the firm visit the class and talk to students about the importance of good drafting drawings in the manufacturing process. If trade secrets are not in jeopardy, ask the company representative to bring representative drawings to class for the students to examine. Skill areas: **Learning skills, learning to learn.**
2. Find a logic diagram for a product, and demonstrate how the diagram was probably used in the manufacturing process. As you discuss Objective 5, demonstrate to the class how logic diagrams can be used for troubleshooting. Skill areas: **Foundation skills, reading and listening.**
3. Have examples of cables and harnesses available to show the class as you study Objectives 15 through 18. Impress upon students that articulate products don't just happen. They are designed and drafted before manufacturing begins. Assign students in small groups to examine cables or harnesses and then report to the class the components they find and what kinds of drawings they believe were needed for assembly workers to complete the products. Skill areas: **Group effectiveness skills, teamwork.**

Resources Used in Developing This Unit

1. Coombs, Clyde F., Jr. *Printed Circuits Handbook*, 3rd ed. NY: McGraw-Hill, 1988.
2. Raskhodoff, Nicholas M. *Electronic Drafting and Design*, 5th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1987.
3. Villanucci, Robert S., et al. *Electronic Techniques Shop Practices and Construction*. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1993.

Suggested Activities

Suggested Supplemental Resources

The *IPC-S-100 Standards and Specifications Manual* is a large, four-volume set of materials vital to designing and packaging electronic circuits. The many items in the set may be ordered separately for instructors interested in a particular area. For information about the *IPC-S-100 Standards and Specifications Manual*, order the latest IPC catalog. For ordering information, call 708-677-2850 or FAX 708-677-9570 or write to:

IPC
Attn: Order Department
7380 N. Lincoln Avenue
Lincolnwood, IL 60646-1705

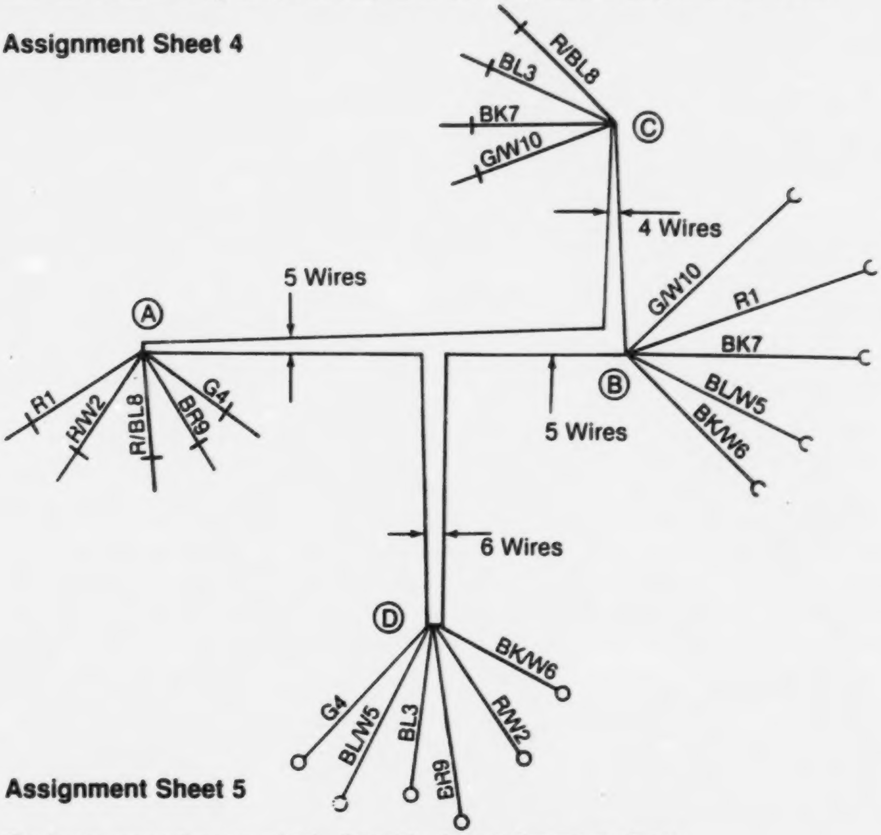
Logic, Schematic, and Other Diagrams
Unit 6

Answers to Assignment Sheets

Assignment Sheets 1, 2, and 3

Evaluated according to criteria listed in the respective assignment sheets.

Assignment Sheet 4



R/BL8
BL3
BK7
G/W10
Ⓒ
4 Wires
5 Wires
Ⓐ
R1
R/W2
R/BL8
BR9
G4
G/W10
R1
BK7
Ⓑ
BL/W5
BK/W6
5 Wires
6 Wires
Ⓓ
BK/W6
G4
BL/W5
BL3
BR9
R/W2

Assignment Sheet 5

Evaluate according to criteria listed in the assignment sheet.

Logic, Schematic, and Other Diagrams
Unit 6

Answers to Written Test

1. a. 6
   b. 3
   c. 10
   d. 13
   e. 11
   f. 7
   g. 12
   h. 4
   i. 1
   j. 8
   k. 9
   l. 2
   m. 5

2. a. Signal flow
   b. Functions

3. a, c, d

4. a, b, d

5. a. Thick
   b. Thin
   c. Upper
   d. A bus

6. a. 5
   b. 9
   c. 12
   d. 18
   e. 16
   f. 3
   g. 6
   h. 17
   i. 15
   j. 13
   k. 1
   l. 7
   m. 10
   n. 14
   o. 11
   p. 4
   q. 2
   r. 8

7. a. 2
   b. 4
   c. 1
   d. 3

8. a. Values
   b. Notes

Answers to Written Test

9.
   a. Libraries
   b. Left, right
   c. Top
   d. Outer
   e. Square
   f. 25mm
   g. An arrowhead
   h. Blank spaces
   i. Identically
   j. Microfilmed

10. a, c, d, f, g

11. In any order:

    a. Dash line method
    b. Bracket method

12.

a.	3	d.	1
b.	5	e.	1
c.	2	f.	4

13. a

14.
    a. AWS
    b. Location

15.
    a. Any three of the following four:

       (1) Ribbon
       (2) Coaxial
       (3) Flat
       (4) Shielded

    b. Any three of the following six:

       (1) Coaxial
       (2) BNC
       (3) Banana plug
       (4) Lug
       (5) Crimp
       (6) Butt

Answers to Written Test

16. a. An end connection diagram
    b. Connectors
    c. Assembly
    d. Wire list

17.

a.	5	d.	7	g.	6
b.	9	e.	8	h.	3
c.	2	f.	1	i.	4

18. a, b

19. a. Exact
    b. A bill of materials and a wire list
    c. Wire list
    d. Symbols

20. a. 2
    b. 3
    c. 1

Logic, Schematic, and Other Diagrams
Unit 6

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

_____a. Pictorial representation of an assembly which contains enough information that the assembly can be manufactured

_____b. The use of squares and rectangles to represent electronic components, subassemblies, or equipment

_____c. A set of data or timing lines with similar functions that are always connected as a group and represented by a single wide line on a block diagram

_____d. A bundle of individual wires, each starting at one end of a bundle and terminating at the opposite end

_____e. A quick, low-resolution plot of a schematic or logic diagram usually made on a dot matrix printer instead of a plotter

_____f. A reference point for most voltage measurements; this point has a zero potential difference between it and earth

_____g. A bundle of wires on a chassis assembly that has leads leaving the main trunk and routed to components, terminals, or subassemblies

1. Power supply
2. Trace
3. Block diagram
4. Logic diagram
5. Wire
6. Assembly drawing
7. Ground
8. Schematic diagram
9. Signal flow
10. Bus
11. Check plot
12. Harness
13. Cable

Written Test

______h. Shows logic functions and gates, but does not provide reference to physical implementation

______i. A source of electromagnetic power such as a DC battery or an AC generator

______j. A line drawing showing all components and how they are connected together without regard to their shape, size, or location; a schematic explains rather than represents a circuit

______k. The direction that current flows through a circuit

______l. A copper path on a printed circuit board that connects one component to another

______m. An electrical conductor made of one or several strands of low resistance metal such as copper surrounded by an insulating material

2. Complete statements about block diagrams and their applications. Circle the material which best completes each of the following statements.

   a. Block diagrams are used to show (**signal flow**) (**component placement**) through a system.

   b. Block diagrams also indicate basic circuit (**arrangements**) (**functions**) by representing groups of components by a single block.

3. Select true statements about guidelines for drawing block diagrams. Place an "X" beside each true statement.

______a. Draw block diagrams with medium width lines and equal height, upper case lettering.

______b. Make connecting lines vertical or horizontal with square corners, and keep crossing lines heavy and very visible.

______c. Normally, put input on the left, arrowheads to indicate direction of flow, and output on the right.

______d. Use two parallel lines to indicate a data bus or timing bus with an arrow at the end to indicate date flow or arrows at both ends to indicate bidirectional flow.

4. Select true statements about logic diagrams and their applications. Place an "X" beside each true statement.

______a. Logic diagrams are used to show circuit logic with logic elements and interconnections.

______b. Logic diagrams also show signal flow direction and waveforms.

______c. Logic diagrams may or may not show component and pin identification.

______d. Logic diagrams are often used as an aid for troubleshooting a circuit.

5. Complete statements about guidelines for drawing logic diagrams. Circle the material that best completes each of the following statements.

a. Always follow ANSI standards for graphic symbols, and use (**thick**) (**thin**) lines to outline symbols.

b. Draw connecting lines as (**thin**) (**thick**) lines vertical or horizontal with square corners.

c. Use equal height, (**lower**) (**upper**) case lettering, and place notes next to elements in open space.

d. Use arrows to indicate data flow, and two parallel lines with arrows at each end to indicate (**an edge connection**) (**a bus**).

Written Test

6. Match logic diagram abbreviations with their meanings. Place the number beside the abbreviation in the blank beside its description.

______a. Blocking oscillator
______b. Clear or reset
______c. Cathode follower
______d. Clock pulse
______e. Emitter follower
______f. Flip flop
______g. Preset
______h. Clk or clock
______i. DO-D, data bus or data lines
______j. AO-A, address bus or address lines
______k. CS, chip select
______l. Number of bits
______m. Register
______n. Register, N stage
______o. Set
______p. Shift register
______q. Schmitt trigger
______r. Toggle or trigger

1. K5
2. ST
3. FF
4. SR
5. BO
6. K1
7. (N)
8. T
9. CL
10. RG
11. S
12. CF
13. K4
14. RG (N)
15. K3
16. EF
17. K2
18. CP

Written Test

7. Match types of schematic drawings with their applications. Place the number beside the schematic type in the blank beside the description of its application.

______a. A large schematic showing all interconnections between subassemblies

______b. A drawing or set of drawings showing the complete electronic assembly

______c. A schematic drawing of one subassembly of a larger assembly

______d. A diagram showing point-to-point electrical connections

1. Functional schematic
2. Assembly schematic
3. Wiring schematic
4. Electronic schematic

8. Complete statements about what schematics do. Circle the material that best completes each of the following statements.

   a. Schematics show component symbols along with their reference designators and component (**sizes**) (**values**).

   b. Along with signal flow, schematics show components connections, subassemblies, and appropriate (**arrows**) (**notes**).

9. Complete statements about guidelines for drawing schematics. Circle the material that best completes each of the following statements.

   a. When drawing a board schematic, use the correct templates, and with CAD schematics, use symbol (**reference designators**) (**libraries**) or create proper symbols.

   b. Develop from (**right**) (**left**) to (**left**) (**right**) and from top to bottom as the signal flows.

   c. Place input or sources at the (**side**) (**top**), and outputs or loads at the bottom.

   d. Place all external connections at the (**lower**) (**outer**) edges of the schematic.

   e. Make connecting lines horizontal or vertical with (**square**) (**rounded**) corners.

   f. Generally, use equal height lettering 3 to 4 mm high, and space lines about (**50mm**) (**25mm**) (**1"**) apart.

g. When flow is not obvious, indicate flow with (**a thick line**) (**an arrowhead**), and use thick lines, if required, to emphasize signal lines.

h. Avoid large (**symbols at edges**) (**blank spaces**).

i. Draw duplicate circuity (**identically**) (**separately**).

j. Although schematics do not have to be drawn to scale or dimensioned, draw symbols large enough that they can be (**microfilmed**) (**easily traced**).

10. Select true statements about guidelines for applying schematic line conventions. Place an "X" beside each true statement.

______a. Draw leader lines, brackets, and other general lines with a thin line.

______b. Draw boundary lines and mechanical groupings with a thin line.

______c. Draw general use symbols and connection lines with a medium line.

______d. Draw mechanical connections, shielding, and future circuits with a medium double-dash line.

______e. For emphasis, use a double-dash line.

______f. Use a bullet to indicate single or multiple junctions, but use plain lines on a crossover.

______g. For continuation of lines, use the arrow method for simple continuations, or the bracket method for more complex continuations.

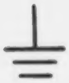
11. List the two methods of stage designation for circuits on schematics. The two may be in any order.

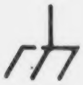
a. ______________________

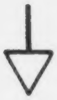
b. ______________________

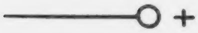
Written Test

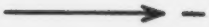
12. Match special symbols with their meanings. Place the number beside the meaning in the blank beside the symbol.

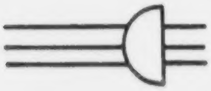
_____a.


_____b.


_____c.


_____d.


_____e.


_____f.


1. DC power supply
2. Common ground
3. General or earth ground
4. AC power supply
5. Chassis or frame ground

13. Select true statements about the purposes of notes on schematics. Place an "X" beside each true statement.

_____a. In general, notes clarify information on a schematic, and also clarify symbol representation.

_____b. Notes are also valuable in troubleshooting equipment.

Written Test

14. Complete statements about elements in a wire list. Circle the material that best completes each of the following statements.

    a. A wire list should include the (**AWG**) (**ANSI**) wire number and type along with a reference connection point.

    b. Other elements in a wire list include color, length, and the (**location**) (**function**) of the wire indication using the notations "from" and "to".

15. List at least three types of cables and cable connectors. Items may appear in any order.

    a. Basic cable types are:

       (1) ____________________

       (2) ____________________

       (3) ____________________

    b. Basic cable connectors include:

       (1) ____________________

       (2) ____________________

       (3) ____________________

16. Complete statements about elements in cable assembly drawings. Circle the material that best completes each of the following statements.

    a. A complete cable assembly drawing should have connectors at each end with (**an end connection diagram**) (**a proper schematic reference**).

    b. The cable assembly should show the length of the finished cable including the end (**terminations**) (**connectors**).

    c. The (**connection**) (**assembly**) method or procedure needs to be indicated.

    d. There should be a complete (**bill of material**) (**wire list**) with gauge, type, color, length of outer jacket, and identification and markings.

Written Test

17. Match harness terms with their definitions. Place the number beside the term in the blank beside its definition.

______a. Two or more unlaced leads leaving a harness assembly at a breakout point

______b. Space between a lace or cable ties where a lead or group of leads leave any portion of a harness

______c. Individual leads leaving a leg at regularly spaced intervals

______d. Overall shape of a harness assembly

______e. Method of bundling individual leads to form a harness

______f. Individual insulated conductor

______g. A minor run of two or more laced leads

______h. A major run of harness assembly containing the largest number of laced leads

______i. The complete route of individual leads in a harness assembly

1. Lead
2. Fanout
3. Trunk
4. Wire run
5. Breakout
6. Leg
7. Harness contour
8. Lacing
9. Breakout point

18. Select true statements about components of a harness. Place an "X" beside each true statement.

______a. A harness includes wire and end connectors.

______b. The bundling materials for a harness include lacing, tie wrap, wire saddles, and clips.

Written Test

19. Complete statements about elements in harness assembly drawings. Circle the material that best completes each of the following statements.

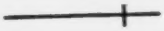
    a. A harness assembly shows the (**approximate**) (**exact**) representation of assembly of interconnecting wires with the measured length of each wire.

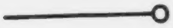
    b. An assembly drawing should have (**a bill of materials and a wire list**) (**only a wire list**).

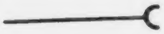
    c. An assembly should include wiring termination numbers to reference the (**bill of materials**) (**wire list**).

    d. A harness assembly drawing should include wiring termination (**schematics**) (**symbols**).

20. Match wiring termination abbreviations with their symbols. Place the number beside the abbreviation in the blank beside the symbol.

_____a. 

_____b. 

_____c. 

1. BS
2. S
3. R

*Permission to duplicate this test is granted.

Logic, Schematic, and Other Diagrams
Unit 6

Unit Evaluation Form

Student Name ______________________ Unit Rating __________

Assignment Sheet 1—Redraw an Existing Schematic Rating ______

Comments: ____

____

Assignment Sheet 2—Sketch a Schematic on Grid Paper Rating ______

Comments: ____

____

Assignment Sheet 3—Draw a Schematic Rating ______

Comments: ____

____

Assignment Sheet 4—Complete and Check a Wire List Rating ______

Comments: ____

____

Assignment Sheet 5—Draw a Harness Layout Rating ______

Comments: ____

____

Assignment Sheet 6—Draw a Block Diagram Rating ______

Comments: ____

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date ____________

Student Signature ______________________________ Date ____________

*Permission to duplicate this form is granted.

Logic, Schematic, and Other Diagrams
Unit 6

Information Sheet

1. **Terms and definitions**

   a. **Assembly drawing** — Pictorial representation of an assembly which contains enough information that the assembly can be manufactured

   b. **Block diagram** — The use of squares and rectangles to represent electronic components, sub-assemblies, or equipment

   c. **Bus** — A set of data or timing lines with similar functions that are always connected as a group and represented by a single wide line on a block diagram

   d. **Cable** — A bundle of individual wires, each starting at one end of a bundle and terminating at the opposite end

   e. **Check plot** — A quick, low-resolution plot of a schematic or logic diagram usually made on a dot matrix printer instead of a plotter

   f. **Ground** — A reference point for most voltage measurements; this point has a zero potential difference between it and earth

   g. **Harness** — A bundle of wires on a chassis assembly that has leads leaving the main trunk and routed to components, terminals, or subassemblies

   h. **Logic diagram** — Shows logic functions and gates, but does not provide reference to physical implementation

   i. **Power supply** — A source of electromagnetic power such as a DC battery or an AC generator

   j. **Schematic diagram** — A line drawing showing all components and how they are connected together without regard to their shape, size, or location; a schematic explains rather than represents a circuit

   k. **Signal flow** — The direction that current flows through a circuit

   l. **Trace** — A copper path on a printed circuit board that connects one component to another

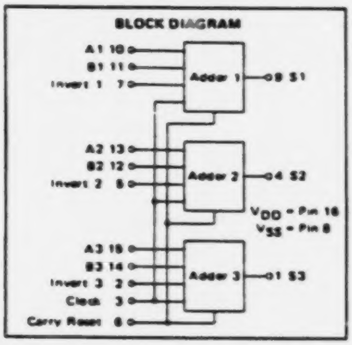
   m. **Wire** — An electrical conductor made of one or several strands of low resistance metal such as copper surrounded by an insulating material

Information Sheet

2. Block diagrams and their applications

a. Block diagrams are used to show signal flow through a system.

b. Block diagrams also indicate basic circuit functions by representing groups of components by a single block.


BLOCK DIAGRAM
A1 10
B1 11
Invert 1 7
Adder 1
9 S1
A2 13
B2 12
Invert 2 5
Adder 2
4 S2
V_{DD} = Pin 16
V_{SS} = Pin 8
A3 15
B3 14
Invert 3 2
Clock 3
Carry Reset 6
Adder 3
1 S3

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3. Guidelines for drawing block diagrams

a. Draw block diagrams with medium width lines and equal height, upper case lettering.

b. Make connecting lines vertical or horizontal with square corners, and keep crossing lines at a minimum.

c. Normally, put input on the left, arrowheads to indicate direction of flow, and output on the right.

d. Use two parallel lines to indicate a data bus or timing bus with an arrow at the end to indicate date flow or arrows at both ends to indicate bidirectional flow.

4. Logic diagrams and their applications

a. Logic diagrams are used to show circuit logic with logic elements and interconnections.

b. Logic diagrams also show signal flow direction and waveforms.

c. Logic diagrams also show component and pin identification.

d. Logic diagrams are often used as an aid for troubleshooting a circuit.

Information Sheet

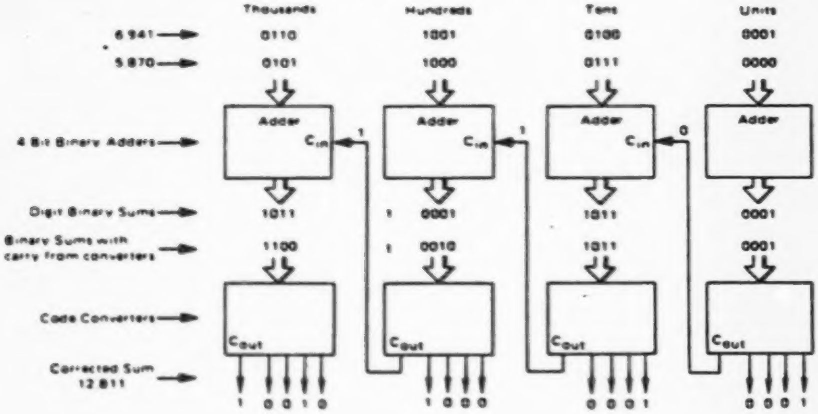
5. **Guidelines for drawing logic diagrams**

   a. Always follow ANSI standards for graphic symbols, and use thick lines to outline symbols.

   b. Draw connecting lines as thin lines vertical or horizontal with square corners.

   c. Use equal height, upper case lettering, and place notes next to elements in open space.

   d. Use arrows to indicate data flow, and two parallel lines with arrows at each end to indicate a bus.


Thousands
Hundreds
Tens
Units
6 941
0110
1001
0100
0001
5 870
0101
1000
0111
0000
4 Bit Binary Adders
Adder
Adder
Adder
Adder
C_{in}
C_{in}
C_{in}
1
1
0
Digit Binary Sums
1011
1 0001
1011
0001
Binary Sums with carry from converters
1100
1 0010
1011
0001
Code Converters
C_{out}
C_{out}
C_{out}
C_{out}
Corrected Sum 12 811
1 0 0 1 0
1 0 0 0
0 0 0 1
0 0 0 1

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6. **Logic diagram abbreviations and their meanings**

   a. **BO** — Blocking oscillator

   b. **CL** — Clear or reset

   c. **CF** — Cathode follower

   d. **CP** — Clock pulse

   e. **EF** — Emitter follower

   f. **FF** — Flip flop

   g. **K1** — Preset

Information Sheet

h. **K2** — Clk or clock

i. **K3** — DO-D, data bus or data lines

j. **K4** — AO-A, address bus or address lines

k. **K5** — CS, chip select

l. **(N)** — Number of bits

m. **RG** — Register

n. **RG(N)** — Register, N stage

o. **S** — Set

p. **SR** — Shift register

q. **ST** — Schmitt trigger

r. **T** — Toggle or trigger

7. **types of schematic drawings AND their applications**

   a. **Assembly schematic** — A large schematic showing all interconnections between subassemblies

   b. **Electronic schematic** — A drawing or set of drawings showing the complete electronic assembly

   c. **Functional schematic** — A schematic drawing of one subassembly of a larger assembly

   d. **Wiring schematic** — A diagram showing point-to-point electrical connections

8. **What schematics diagrams do**

   a. Schematics show component symbols along with their reference designators and component values.

   b. Along with signal flow, schematics show components connections, subassemblies, and appropriate notes.

Information Sheet

9. Guidelines for drawing schematics

a. When drawing a board schematic, use the correct templates, and with CAD schematics, use symbol libraries or create proper symbols.

b. Develop from left to right and from top to bottom as the signal flows.

c. Place input or sources at the top, and outputs or loads at the bottom.

d. Place all external connections at the outer edges of the schematic.

e. Make connecting lines horizontal or vertical with square corners.

f. Generally, use equal height lettering 3 to 4 mm high, and space lines about 1" apart.

g. When flow is not obvious, indicate flow with an arrowhead, and use thick lines, if required, to emphasize signal lines.

h. Avoid large blank spaces.

i. Draw duplicate circuity identically.

j. Although schematics do not have to be drawn to scale or dimensioned, draw symbols large enough that they can be microfilmed.

Information Sheet

10. Guidelines for applying schematic line conventions

a. Draw leader lines and brackets with a thin line.

Thin

b. Draw boundary lines and mechanical groupings with a thin double-dash line.

Thin

c. Draw general use symbols and connection lines with a medium line.

Medium

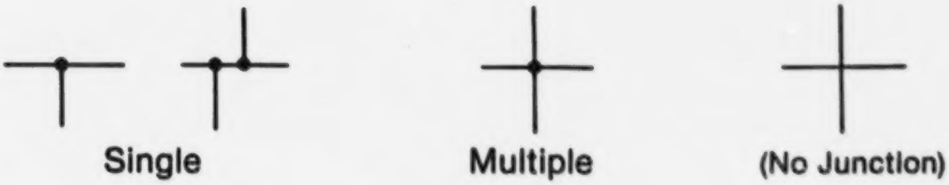
d. Draw mechanical connections, shielding, and future circuits with a medium double-dash line.

Medium

e. For emphasis, use a thick line.

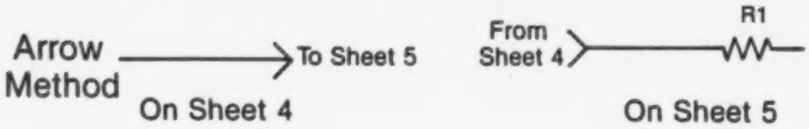
Thick

f. Use a bullet to indicate single or multiple junctions, but use plain lines on a crossover.

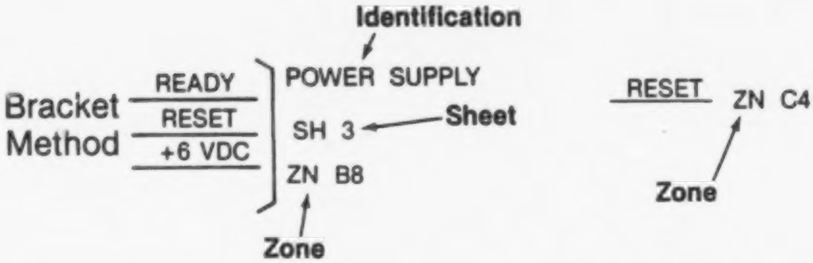


Information Sheet

g. For continuation of lines, use the arrow method for simple continuations, or the bracket method for more complex continuations.


Arrow Method
To Sheet 5
On Sheet 4
From Sheet 4
R1
On Sheet 5

Arrow method


Identification
Bracket Method
READY
RESET
+6 VDC
POWER SUPPLY
SH 3
Sheet
ZN B8
Zone
RESET
ZN C4
Zone

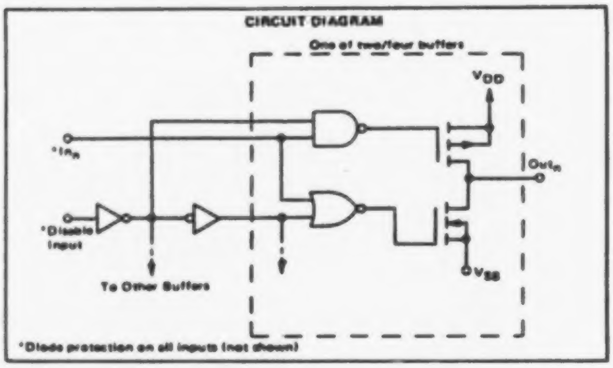
Continued on Another Sheet

Continued on Same Page

Bracket method

11. Methods of stage designation for circuits on schematics

a. Dash line method


CIRCUIT DIAGRAM
One of two/four buffers
VDD
*In_n
Out_n
*Disable Input
To Other Buffers
VSS
*Diode protection on all inputs (not shown)

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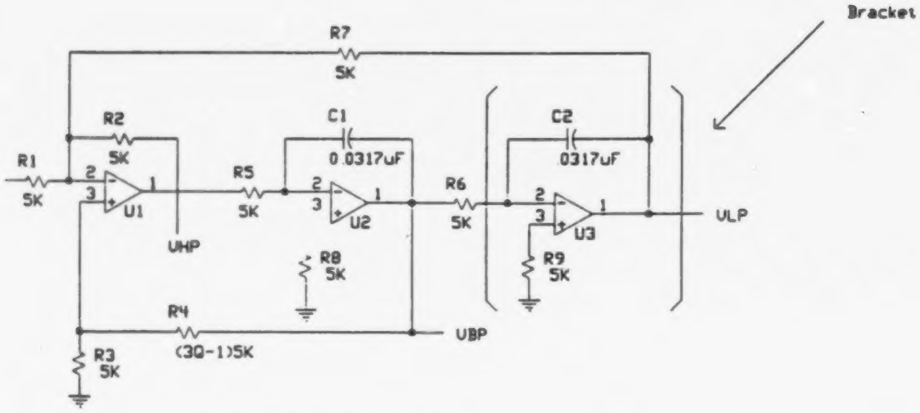
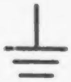
Information Sheet

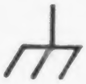
b. Bracket method

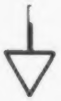

Bracket
R7
5K
R2
5K
C1
0.0317uF
C2
.0317uF
R1
5K
R5
5K
R6
5K
2
3
1
U1
U2
U3
UHP
ULP
R8
5K
R9
5K
R4
(3Q-1)5K
UBP
R3
5K

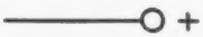
STATE-VARIABLE FILTER

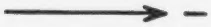
12. Special symbols and their meanings

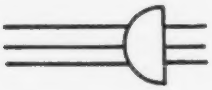
a.  —General or earth ground

b.  —Chassis or frame

c.  —Common ground

d.  —DC power supply

e.  —DC power supply

f.  —AC power supply

13. **Purposes of notes on schematics**

    a. In general, notes clarify information on a schematic, and also clarify symbol representation.

    b. Notes are also valuable in helping avoid the repetition of abbreviations of measuring units.

14. **Elements in a wire list**

    a. A wire list should include the AWG wire number and type along with a reference connection point.

    b. Other elements in a wire list include color, length, and the location of the wire indication using the notations "from" and "to".

Information Sheet

15. Types of cables and cable connectors

a. The four basic cable types are:

   (1) Ribbon

   (2) Coaxial

   (3) Flat

   (4) Shielded

b. Basic cable connectors include:

   (1) Coaxial

   (2) BNC

   (3) Banana plug

   (4) Lug

   (5) Crimp

   (6) Butt

16. Elements in cable assembly drawing

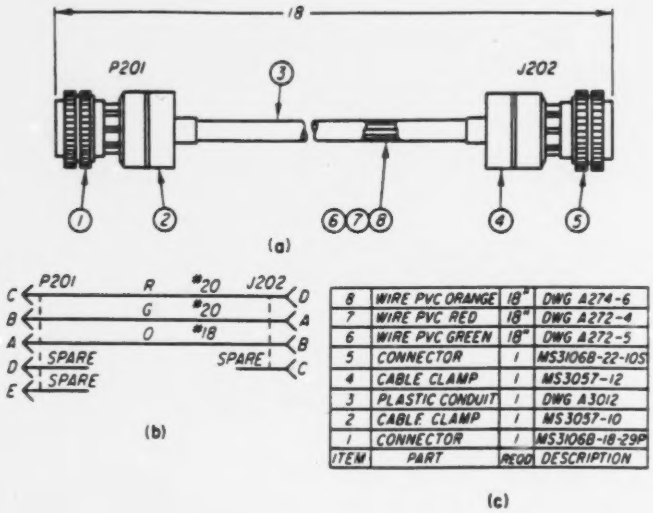
a. A complete cable assembly drawing should have connectors at each end with an end connection diagram.

b. The cable assembly should show the length of the finished cable including the end connectors.

c. The assembly method or procedure needs to be indicated.

Information Sheet

d. There should be a complete wire list with gauge, type, color, length of outer jacket, and identification and markings.



(a)

(b)

ITEM	PART	REQD	DESCRIPTION
8	WIRE PVC ORANGE	18"	DWG A274-6
7	WIRE PVC RED	18"	DWG A272-4
6	WIRE PVC GREEN	18"	DWG A272-5
5	CONNECTOR	1	MS3106B-22-10S
4	CABLE CLAMP	1	MS3057-12
3	PLASTIC CONDUIT	1	DWG A3012
2	CABLE CLAMP	1	MS3057-10
1	CONNECTOR	1	MS3106B-18-29P

(c)

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17. Harness terms and their definitions

a. **Breakout** — Two or more unlaced leads leaving a harness assembly at a breakout point

b. **Breakout point** — Space between a lace or cable ties where a lead or group of leads leave any portion of a harness

c. **Fanout** — Individual leads leaving a leg at regularly spaced intervals

d. **Harness contour** — Overall shape of a harness assembly

e. **Lacing** — Method of bundling individual leads to form a harness

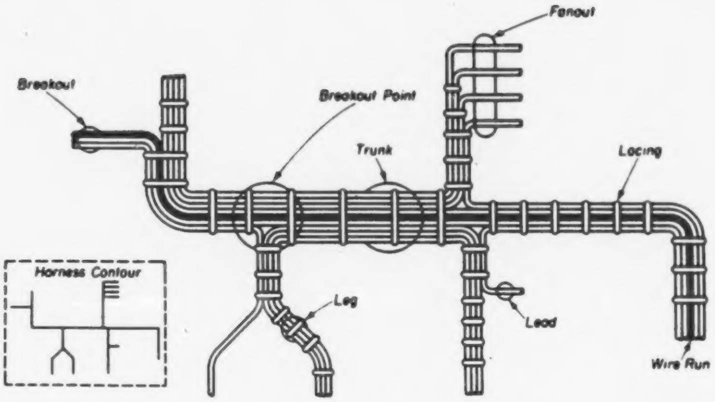
f. **Lead** — Individual insulated conductor

g. **Leg** — A minor run of two or more laced leads

h. **Trunk** — A major run of harness assembly containing the largest number of laced leads

Information Sheet

i. **Wire run** — The complete route of individual leads in a harness assembly



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18. Components of a harness

a. A harness includes wire and end connectors.

b. The bundling materials for a harness include lacing, tie wrap, wire saddles, and clips.

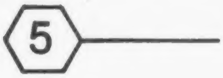
19. Elements in harness assembly drawings

a. A harness assembly shows the exact representation of assembly of interconnecting wires with the measured length of each wire.

b. An assembly drawing should have a bill of materials and a wire list.

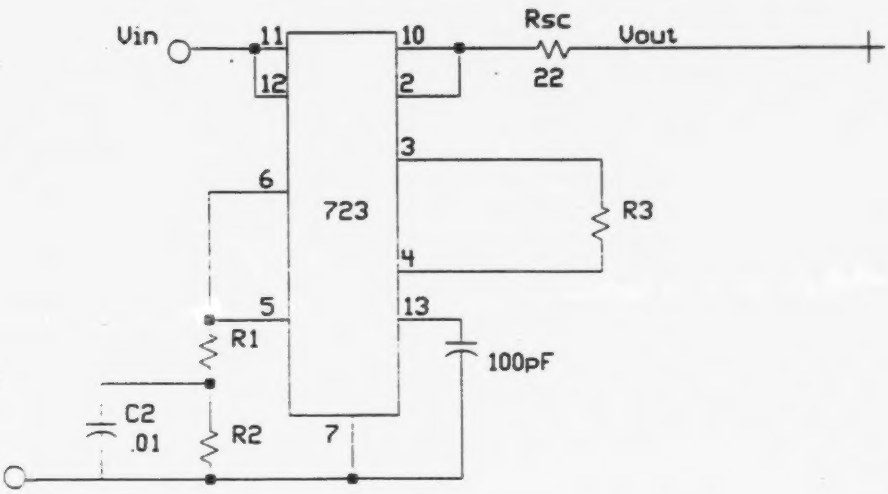
c. An assembly should include wiring termination numbers to reference the wire list.

Example:



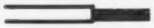
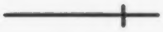
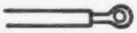
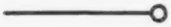
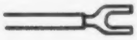
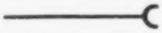
Information Sheet

d. A harness assembly drawing should include wiring termination symbols.


Vin
11
12
10
2
Rsc
22
Vout
3
6
723
R3
4
5
13
R1
100pF
C2
.01
R2
7

Schematic diagram

20. **Wiring termination abbreviations and their symbols**

a.	**S (Strip)**	Termination:		Symbol:	
b.	**R (Ring)**	Termination:		Symbol:	
c.	**BS (Block Spade)**	Termination:		Symbol:	

Logic, Schematic, and
Other Diagrams
Unit 6

Assignment Sheet 1—Draw an Existing Schematic

Name ____________________ Overall Rating ________

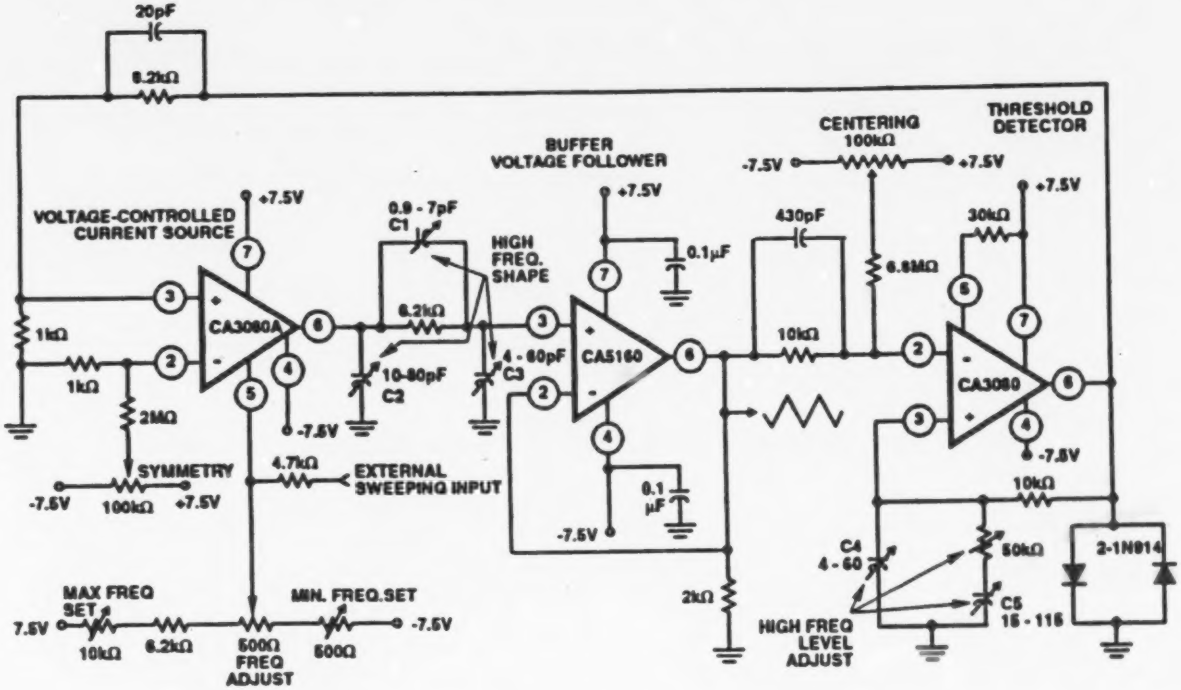
Evaluation Criteria	**Rating**
Schematic properly redrawn	______
Proper reference designations shown	______
Parts list included on schematic	______

Directions: Select appropriate media or on a CAD system, redraw the schematic on the following page. Show reference designations and include a parts list on the schematic.

CAD Alert: You can save a world of time by using a CAD symbol library with this assignment, or by creating your own symbols on the CAD system. Once symbols are available, they can be used over and over again to save time in the future.

Assignment Sheet 1

CA5160 1,000,000/1 SINGLE CONTROL FUNCTION GENERATOR — 1 Mz TO 1Hz


20pF
8.2kΩ
VOLTAGE-CONTROLLED
CURRENT SOURCE
+7.5V
7
3
2
CA3080A
6
5
4
-7.5V
1kΩ
1kΩ
2MΩ
SYMMETRY
-7.5V
100kΩ
+7.5V
4.7kΩ
EXTERNAL
SWEEPING INPUT
0.9 - 7pF
C1
HIGH
FREQ.
SHAPE
8.2kΩ
10-80pF
C2
4 - 60pF
C3
BUFFER
VOLTAGE FOLLOWER
+7.5V
0.1μF
CA5160
0.1
μF
-7.5V
2kΩ
MAX FREQ
SET
7.5V
10kΩ
8.2kΩ
500Ω
FREQ
ADJUST
MIN. FREQ.SET
500Ω
-7.5V
CENTERING
100kΩ
-7.5V
+7.5V
430pF
6.8MΩ
10kΩ
THRESHOLD
DETECTOR
+7.5V
30kΩ
CA3080
-7.5V
10kΩ
C4
4 - 60
50kΩ
C5
15 - 115
HIGH FREQ
LEVEL
ADJUST
2-1N914

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Logic, Schematic, and Other Diagrams
Unit 6

Assignment Sheet 2—Sketch a Schematic on Grid Paper

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Schematic properly sketched	______
Sketch enlarged to appropriate size	______
Values of components properly listed	______

Directions: On appropriate grided media, sketch the schematic on the following page or use a schematic furnished by your instructor. Enlarge the sketch to an appropriate size, and show the component values as listed below.

Component Values

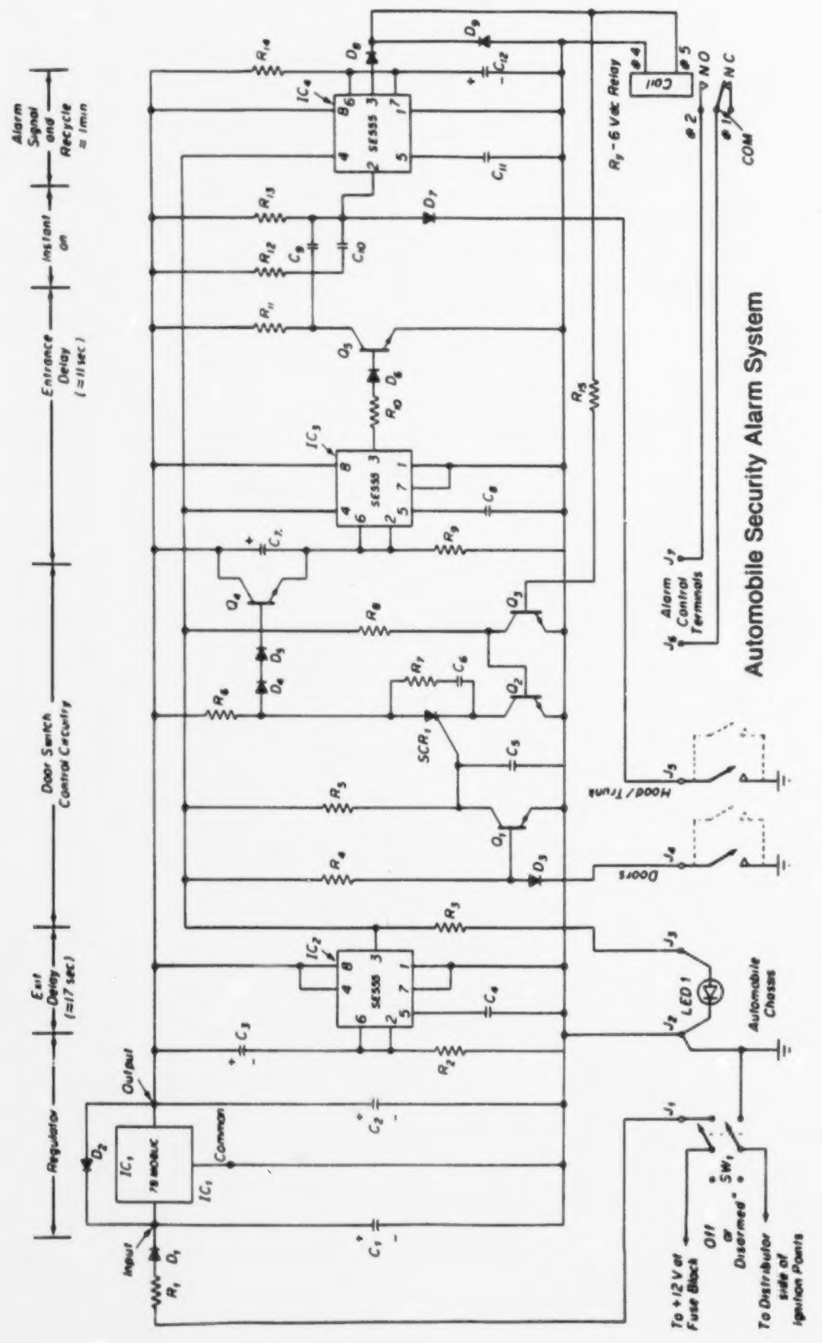
R_1 = 1K
R_2 = 15K
R_3 = 680
R_4 = 22K
R_5 = 2.2K
R_6 = 560
R_7 = 18K
R_8 = 560
R_9 = 15K
R_{10} = 1K
R_{11} = 2.4K
R_{12} = 51K
R_{13} = 47K
R_{14} = 22K

D_1 = 1N914
D_2 = 1N914
D_3 = 1N914
D_4 = 1N914
D_5 = 1N914
D_6 = 1N914
D_7 = 1N914

Q_1 = 2N3422
Q_2 = 2N2219
Q_3 = 2N3422

C_1 = 15µF
C_2 = 22µF
C_3 = .05µF
C_4 = .01µF
C_5 = 15µF
C_6 = .047µF
C_7 = .01µF
C_8 = 25µF
C_9 = 25µF
C_{10} =3.3µF
C_{11} = .01µF
C_{12} = 25µF

Assignment Sheet 2


Regulator
Exit Delay (≈17 sec)
Door Switch Control Circuitry
Entrance Delay (≈11 sec)
Instant on
Alarm Signal and Recycle ≈ 1min
Input
Output
Common
IC1
78 M08UC
D1
D2
R1
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
IC2
IC3
IC4
SE555
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
D3
D4
D5
D6
D7
D8
D9
Q1
Q2
Q3
Q4
Q5
SCR1
J1
J2
J3
J4
J5
J6
J7
LED 1
Automobile Chassis
Doors
Hood/Trunk
To +12 V at Fuse Block
Off or Disarmed
SW1
To Distributor side of Ignition Points
Alarm Control Terminals
R7 - 6 Vdc Relay
Coil
#1
#2
#4
#5
NO
NC
COM

Automobile Security Alarm System

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Logic, Schematic, and Other Diagrams
Unit 6

Assignment Sheet 3—Draw a Schematic

Name ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Schematic properly drawn	____
Proper media used	____
Schematic neatly printed	____

Directions: On appropriate media or on a CAD system, draw the schematic you created in Assignment Sheet 2, or use a schematic sketch furnished by your instructor. If available, use plastic lead and reproduce the schematic on polyester media such as Mylar.

CAD Alert: For neatness, remember there are no clues left when corrections are made on a CAD system. To make this assignment particularly effective, plot the schematic on polyester with a pen plotter.

Logic, Schematic, and Other Diagrams
Unit 6

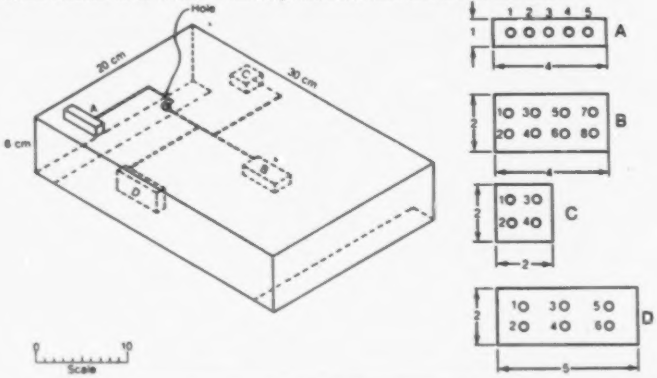
Assignment Sheet 4—Draw a Harness Layout

Name ______________________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Harness layout properly executed	______
Color abbreviations properly used	______
Wire list correct and complete	______

Directions: On appropriate drafting media, draw with zones a full size wiring harness layout using the information detailed in the following materials. Use references as needed to complete a wiring list in a proper format. Examine the harness layout example on the back side of this sheet before you start, and reference the example as you continue this assignment.

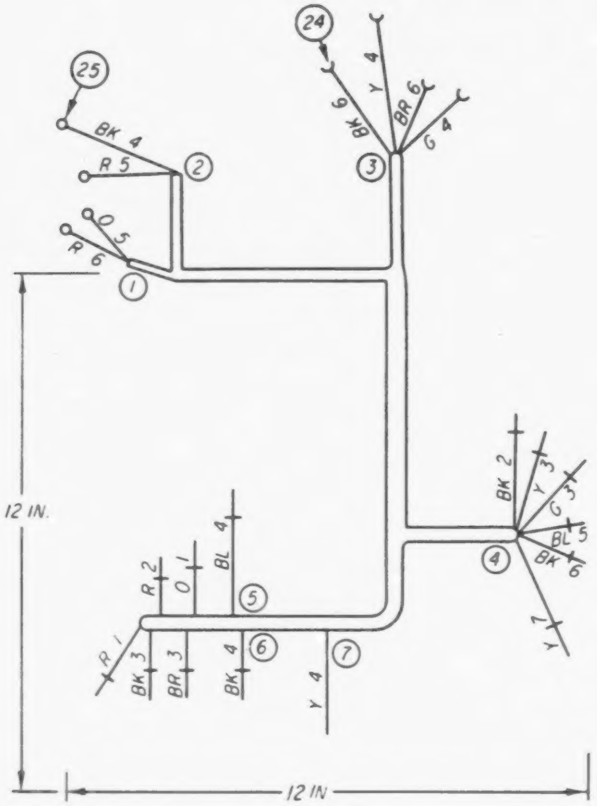
Given: Chassis is 20 × 30 × 6 cm deep. Insulated wire size OD 1.5 mm AWG



Wiring List					
Wire No.	Color	From	Termination	To	Termination
1	Red	B5	BS	A3	S
2	Red/White	A2	S	D6	R
3	Blue	D3	R	C1	S
4	Green	D2	R	A5	S
5	Blue/white	D2	R	B3	BS
6	Black/white	D5	R	B2	BS
7	Black	C2	S	B4	BS
8	Red/Blue	A3	S	C3	S
9	Brown	D4	R	A4	S
10	Green/white	B6	BS	C4	S

Assignment Sheet 4

Example: Typical harness layout


25
24
BK 4
R 5
2
O 5
R 6
1
BK 6
Y 4
BR 6
G 4
3
12 IN.
BK 2
Y 3
G 3
BL 5
BK 6
4
Y 7
R 2
O 1
BL 4
5
R 1
BK 3
BR 3
BK 4
6
7
Y 4
12 IN

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(NOTE: Use the following abbreviations to label your layout.)

CONDUCTOR COLOR ABBREVIATIONS	
Color	Abbreviation
Black	BK
Brown	BR
Red	R
Orange	O
Yellow	Y
Green	G
Blue	BL
Violet	V
Gray	GY
White	W

Logic, Schematic, and
Other Diagrams
Unit 6

Assignment Sheet 5—Draw a Block Diagram

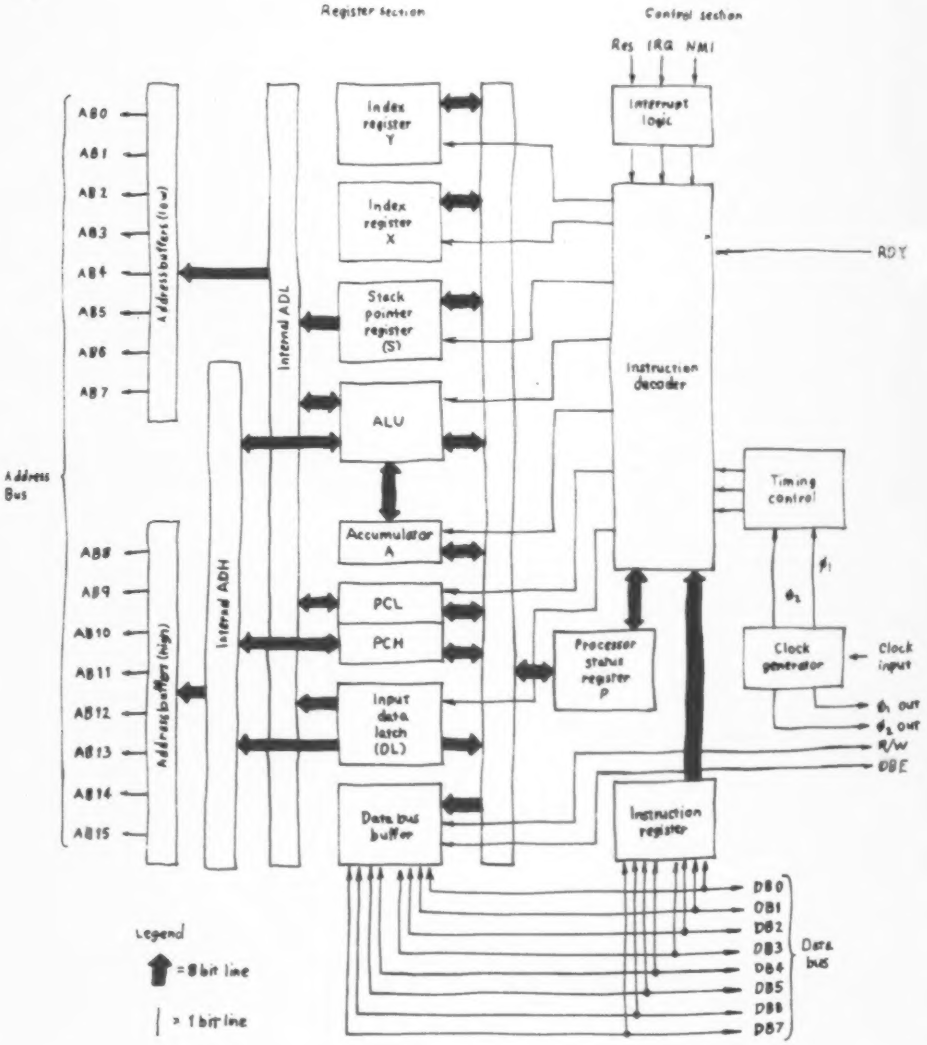
Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Block diagram properly drawn	______
Pen plotter used to print diagram	______
Neatness of lines and lettering	______

Directions: On appropriate media or on a CAD system, draw a block diagram of the block diagram in the following sketch. If available, use plastic lead on polyester film, or if using a CAD system, use a pen plotter.

CAD Alert: The many lines and arrows required in some block diagrams can readily lead to errors and the need for corrections. With CAD, you simply delete errors and redraw. All drawings can be neat with no visible corrections.

Assignment Sheet 5


Register section
Control section
Res
IRQ
NMI
Interrupt logic
AB0
AB1
AB2
AB3
AB4
AB5
AB6
AB7
Address Bus
AB8
AB9
AB10
AB11
AB12
AB13
AB14
AB15
Address buffers (low)
Address buffers (high)
Internal ADL
Internal ADH
Index register Y
Index register X
Stack pointer register (S)
ALU
Accumulator A
PCL
PCH
Input data latch (DL)
Data bus buffer
Instruction decoder
RDY
Timing control
φ1
φ2
Clock generator
Clock input
Processor status register P
φ1 out
φ2 out
R/W
DBE
Instruction register
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
Data bus
Legend
= 8 bit line
= 1 bit line

Electronic Packaging Design
Unit 7

Objective Sheet

Unit Objective

After completing this unit, the student should be able to make a board outline drawing, draw "outline" dolls for components, sketch packages and dimensions from catalogs, and design and draw a design package. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electronic packaging design with their correct definitions.
2. Match elements of electronic package design with their considerations.
3. Complete statements about types of commercial chassis configurations.
4. Complete statements about dimensioning techniques for electronic packaging.
5. Solve problems using guidelines for package layout.
6. Use datum dimensioning to make a board outline drawing. (Assignment Sheet 1)
7. Draw component outline "dolls." (Assignment Sheet 2)
8. Draw chassis and package types from manufacturers' catalogs. (Assignment Sheet 3)
9. Design and draw an electronic package. (Assignment Sheet 4)

Electronic Packaging Design
Unit 7

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Classic II Cabinet Racks (Objective 3)
   TM 2—Styrene Plastic Boxes (Objective 3)
   TM 3—Datum-Line Drafting Techniques (Objective 4)

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

Suggested Activities

14. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Be sure to make transparencies from the transparency masters provided with this unit. These serve to reinforce specific objectives. Review the TMs and prepare samples of the items they display. Permit students to examine samples as you discuss the objectives and show the TMs. Skill areas: **Learning skills, learning to learn.**

2. When teaching Objective 3, have sample chassis available for the students to examine. Assign different groups to different chassis. Have the groups examine the chassis for cut-outs, tooling holes, mounting holes, and connections from the PC boards to the terminals on the chassis. Have the groups report their findings to the class. Skill areas: **Group effectiveness skills, teamwork.**

3. Obtain the PC boards and all major component parts for an electronic project. Obtain a suitable chassis and explain to the students how to arrange them to obtain the most suitable chassis layout in relation to the considerations discussed in Objective 2. Skill areas: **Foundation skills, listening.**

Resources Used in Developing This Unit

1. *903 Engineering Manual & Purchasing Guide*. Fort Worth, TX: Allied Electronics, a Subsidiary of Hall-Mark Electronics Corporation, 1993.

2. *Archer Semiconductor Reference Guide*. Fort Worth, TX: Radio Shack, a Division of Tandy Corporation, 1991.

3. Baer, Charles J. and John R. Ottaway. *Electrical and Electronic Drawing*, 5th ed. New York: McGraw-Hill, Inc., 1986.

4. Raskhodoff, Nicholas M. *Electronic Drafting and Design*, 5th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1987.

5. Villanucci, Robert S., et al. *Electronic Techniques Shop Practices and Construction*. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1993.

Suggested Activities

Suggested Supplemental Resources

The **IPC**, The Institute for Interconnecting and Packaging Electronic Circuits, has available one of their newest technology manuals. Title *Electronic Packaging Handbook*, the handbook ranges from a general introduction to electronic packaging, system integration, and subsystem components and intraconnections, plus many more items essential to the electronic packaging industry. Order number if **IPC-PD-335**. For ordering information, call 708-677-2850 or FAX 708-677-9570 or write to:

IPC
Attn: Order Department
7380 N. Lincoln Avenue
Lincolnwood, IL 60646-1705

Electronic Packaging Design
Unit 7

Answers to Assignment Sheets

Assignment Sheets 1, 2, 3, and 4

Evaluate according to criteria listed in the respective assignment sheets.

Electronic Packaging Design
Unit 7

Answers to Written Test

1. a. 8
   b. 6
   c. 10
   d. 2
   e. 9
   f. 4
   g. 1
   h. 7
   i. 3
   j. 5

2. a. 5
   b. 2
   c. 7
   d. 3
   e. 6
   f. 4
   g. 1

3. a. U-shapes
   b. Military
   c. Plastic

4. a. Used
   b. Perpendicular
   c. Not cumulative

5. a. 2
   b. 3

Electronic Packaging Design
Unit 7

Written Test

Name ______________________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. Relating to the study or appreciation of beauty

______b. A drawing of the physical shape of a PC board or boards that are to be mounted in a package

______c. A drawing that shows the contour and overall dimensions of the components inside an outline

______d. Done for the sake of improving appearance

______e. A container used for mounting printed circuit boards; sometimes called an electronic package

______f. An outline drawing of a component drawn 2X or 4X its actual size

______g. A metal configuration used to dissipate heat generated by electronic devices

______h. Holes used for mounting a printed circuit board to a chassis or a package

______i. Holes used for registration or indexing of a PC board or artwork

______j. The height of components relative to the surface of a printed circuit board

1. Heat sink
2. Cosmetic
3. Tooling holes
4. Doll
5. Topographical
6. Board outline
7. Mounting holes
8. Aesthetic
9. Chassis
10. Component outline drawing

Written Test

2. Match elements of electronic package design with their considerations. Place the number beside the element in the blank beside the consideration.

______a. Determined by the dimensions of the printed circuit board

______b. Based on the function of the product

______c. Often a more critical factor than minimum package size for stationary applications such as home stereos

______d. Physical size and weight must be minimal, but certain dimensions and contours must blend in pleasingly with the total environment in such dedicated applications as automotive stereos

______e. Determined by careful evaluation of circuit functions, size restrictions, component accessibility, and available manufacturing facilities

______f. Determined by the weight of the heaviest components, but requires attention to the cosmetic needs of user controls and indicators, and safety requirements

______g. The goal of electronic packaging—a design mounted in a commercially available chassis with a minimal amount of package modification

1. Standard package
2. Weight requirement
3. Aesthetics
4. Style
5. Minimum space requirement
6. Chassis configuration
7. Cosmetic acceptability

3. Complete statements about types of commercial chassis configurations. Circle the material that best completes each of the following statements.

   a. The most popular commercial chassis configurations are (**X-shapes**) (**U-shapes**), standard boxes, small utility boxes, front panel enclosures, bevel-top consoles, and portable equipment cases.

   b. Standard rack mounted chassis are used for many (**commercially**) (**military**) and industrial applications.

   c. (**Aluminum**) (**Plastic**) enclosures are a good choice for prototypes because they are inexpensive, and easy to machine and drill.

Written Test

4. Complete statements about dimensioning techniques for electronic packaging. Circle the material that best completes each of the following statements.

   a. Datum-line drafting techniques are the techniques most commonly (**required**) (**used**) for electronic packaging.

   b. Datum-line drafting uses any two (**horizontal**) (**perpendicular**) edges of an object for reference, and the lines extending from these edges are called datum-lines.

   c. In datum-line drafting, each dimension is (**independent of**) (**dependant on**) all others, so it is preferred for electronic packaging because errors are (**not cumulative**) (**cumulative**).

5. Solve problems using guidelines for package layout. Circle the number of the statement that best solves each of the following problems.

   a. You've been assigned the job of getting an electronic package project started. You have the PC boards for the project, so to solve the problem of where to start, you should:

      (1) Go to your CAD library and pull up the symbols you'll need.

      (2) Create dolls to represent the printed circuit boards.

      (3) Turn the PC board schematics in to board outline drawings.

   b. You note that your electronic project package calls for several user controls. Your problem is not to create a bigger problem, so you should:

      (1) Carefully identify all user controls on the doll.

      (2) Label the user controls as they are labeled in the appropriate supply catalog.

      (3) Make sure user controls are so mounted on the PC board that they protrude through the chassis.

***Permission to duplicate this test is granted.**

Electronic Packaging Design
Unit 7

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Use Datum Dimensioning to Make a Board Outline Drawing Rating _____

Comments: ______________________________

____

Assignment Sheet 2—Draw Component Outline "Dolls" Rating _____

Comments: ______________________________

____

Assignment Sheet 3—Draw Chassis and Package Types From Manufacturers' Catalogs Rating _____

Comments: ______________________________

____

Assignment Sheet 4—Design and Draw an Electronic Package Rating _____

Comments: ______________________________

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ______________________________

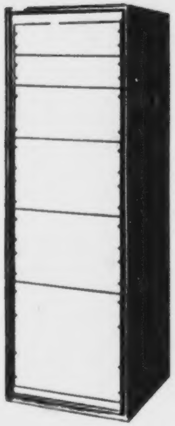
____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

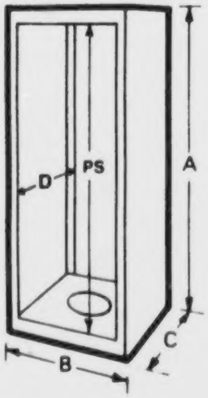
***Permission to duplicate this form is granted.**

Classic II Cabinet Racks



Refined styling, design simplicity. Rigid aluminum extruded trim with black plastic insert frames the front - a few reasons why the Classic II sets your product apart from the conventional.

Classic II Cabinet Racks include welded frame, top, bottom, sides, rear door with cam lock.



Catalog Number	Catalog Number	Panel Space	Outside Height	Outside Width	Outside Depth	Clear Inside Depth	Est. Weight (Lbs.)
NON-VENTILATED	VENTILATED	PS	A	B	C	D	
AGR-9522	AGR-9572	42"	47 5/16"	22"	18 1/2"	17"	110
AGR-9523	AGR-9573	52 1/2"	57 13/16"	22"	18 1/2"	17"	124
AGR-9524	AGR-9574	61 1/4"	66 9/16"	22"	18 1/2"	17"	139
AGR-9525	AGR-9575	70"	75 5/16"	22"	18 1/2"	17"	151
AGR-9526	AGR-9576	78 3/4"	84 1/16"	22"	18 1/2"	17"	163
AGR-9532	AGR-9582	42"	47 5/16"	22"	25 1/2"	24"	128
AGR-9533	AGR-9583	52 1/2"	57 13/16"	22"	25 1/2"	24"	145
AGR-9534	AGR-9584	61 1/4"	66 9/16"	22"	25 1/2"	24"	162
AGR-9535	AGR-9585	70"	75 5/16"	22"	25 1/2"	24"	175
AGR-9536	AGR-9586	78 3/4"	84 1/16"	22"	25 1/2"	24"	189
AGR-9542	AGR-9592	42"	47 5/16"	22"	30 3/4"	29 1/4"	143
AGR-9543	AGR-9593	52 1/2"	57 13/16"	22"	30 3/4"	29 1/4"	160
AGR-9544	AGR-9594	61 1/4"	66 9/16"	22"	30 3/4"	29 1/4"	180
AGR-9545	AGR-9595	70"	75 5/16"	22"	30 3/4"	29 1/4"	194
AGR-9546	AGR-9596	78 3/4"	84 1/16"	22"	30 3/4"	29 1/4"	209

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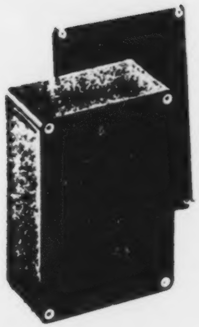
Plastic Boxes

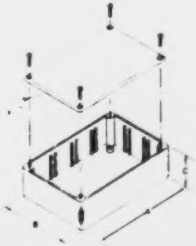
Design Features For Style A:

- KJB Cycolac Thermoplastic with flammability rating of 94V-O at .080" thickness and continuous use temperature of 70°C.
- Card Guides accept .062" thick cards.
- Comes with close fitting interlocking lid and assembly hardware.
- Finish—Black is standard. Special colors are available on request.



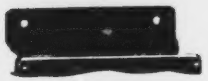
Catalog No.	Weight	A	B	C
CU 281	4.5 oz	4½	3	1¼
CU 282	6.5 oz.	4½	4½	2¼
CU-283	8.5 oz	6	4½	2¼
CU-284	10.5 oz.	7½	4½	2¼

Dimensions are ± .010"



Two styles of mounting brackets, depending on size of Utilibox needed. To order, add suffix -MB to Utilibox catalog number. Brackets are attached at factory and shipped as one unit. (Add .5 oz.)

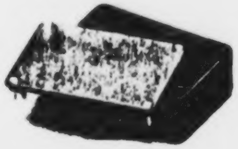
CU 281 MB



CU-282-MB Thru CU-284-MB

Design Features For Style C:

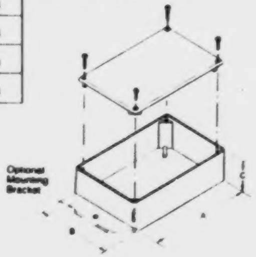
- KJB Cycolac plastic with 94V-O flammability rating at .080" thickness and continuous use temperature of 70°C.
- Comes with close-fitting interlocking lid and assembly hardware.
- Lid includes special corner flange for optional bonding.
- Finish—mar-resistant Black Textured is standard. Special colors available on request.



Catalog No.	Weight	A	B	C
CU-382	2 oz.	3¼	2⅜	1
CU-383	3 oz.	4⅛	2¾	1
CU-384	3 oz.	3¼	3¼	1¼
CU-385	3.5 oz.	4½	3¼	1¼
CU-386	4.5 oz.	5½	3¾	1¼
CU-387	5.6 oz.	5½	4¼	1¾

Dimensions are ± .010"

Optional molded in mounting brackets are available. To order, add suffix -MB to catalog number. (Add .5 oz.)



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Electronic Packaging Design
Unit 7

Information Sheet

1. **Terms and definitions**

   a. **Aesthetic** — Relating to the study or appreciation of beauty

   b. **Board outline** — A drawing of the physical shape of a PC board or boards that are to be mounted in a package

   c. **Component outline drawing** — A drawing that shows the contour and overall dimensions of the components inside an outline

   d **Cosmetic** — Done for the sake of improving appearance

   e. **Chassis** — A container used for mounting printed circuit boards; sometimes called an electronic package

   f. **Doll** — An outline drawing of a component drawn 2X or 4X its actual size

   g. **Heat sink** — A metal configuration used to dissipate heat generated by electronic devices

   h. **Mounting holes** — Holes used for mounting a printed circuit board to a chassis or a package

   i. **Tooling holes** — Holes used for registration or indexing of a PC board or artwork

   j. **Topographical** — The height of components relative to the surface of a printed circuit board

2. **Elements of electronic package design and their considerations**

   a. **Minimum space requirement** — Determined by the dimensions of the printed circuit board

   b. **Weight requirement** — Based on the function of the product

   c. **Cosmetic acceptability** — Often a more critical factor than minimum package size for stationary applications such as home stereos

   d. **Aesthetics** — Physical size and weight must be minimal, but certain dimensions and contours must blend in pleasingly with the total environment in such dedicated applications as automotive stereos

Information Sheet

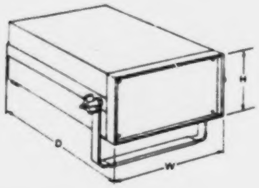
e. **Chassis configuration** — Determined by careful evaluation of circuit functions, size restrictions, component accessibility, and available manufacturing facilities

f. **Style** — Determined by the weight of the heaviest components, but requires attention to the cosmetic needs of user controls and indicators, and safety requirements

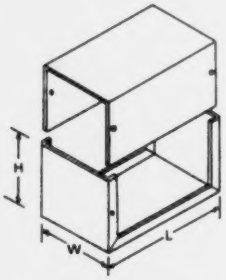
g. **Standard package** — The goal of electronic packaging—a design mounted in a commercially available chassis with a minimal amount of package modification

3. Types of commercial chassis configurations

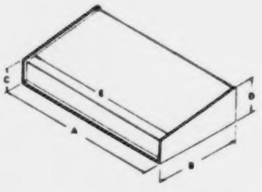
a. The most popular commercial chassis configurations are U-shapes, standard boxes, small utility boxes, front panel enclosures, bevel-top consoles, and portable equipment cases.



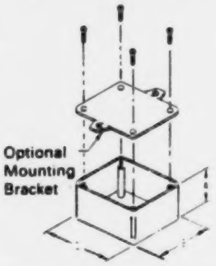
Portable equipment case



U-shaped enclosure



Keyboard styling console



Small utility box

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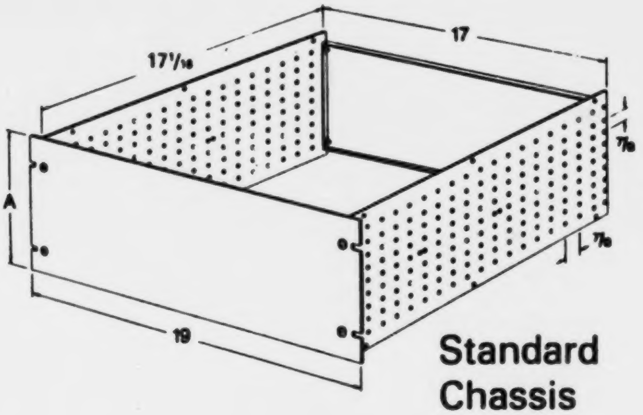
Information Sheet

b. Standard rack mounted chassis are used for many military and industrial applications.



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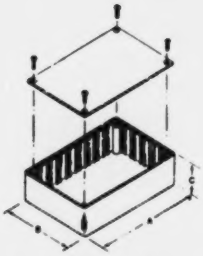
c. Plastic enclosures are a good choice for prototypes because they are inexpensive, and easy to machine and drill.

CAUTION: Do not use plastic enclosures for applications subject to high frequencies or high heat.



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4. Dimensioning techniques for electronic packaging

a. Datum-line drafting techniques are the techniques most commonly used for electronic packaging.

b. Datum-line drafting uses any two perpendicular edges of an object for reference, and the lines extending from these edges are called datum-lines.

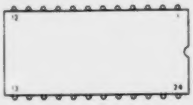
Information Sheet

c. In datum-line drafting, each dimension is independent of all others, so it is preferred for electronic packaging because errors are not cumulative.

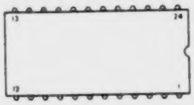
5. Guidelines for package layout

a. Create dolls to represent printed circuit boards and any major hardware component not available.

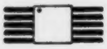
(1) DIP, component side



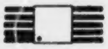
(2) DIP, circuit side



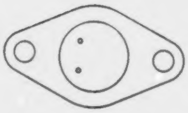
(3) Flat pack, component side



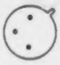
(4) Flat pack, circuit side



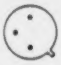
(5) TO-66



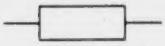
(6) TO-5, component side



(7) TO-5, circuit side



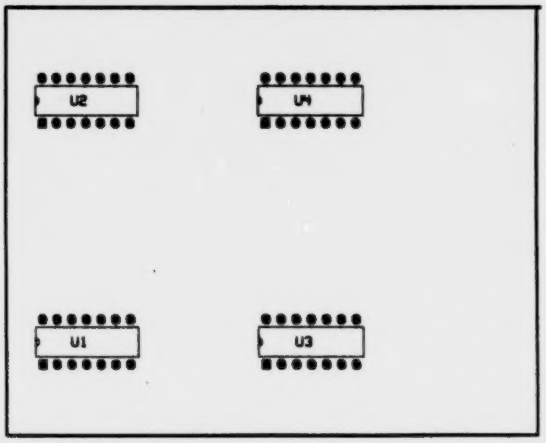
(8) Axial lead



b. Position each component and doll on the chassis or a piece of cardboard or plexiglass.

Information Sheet

c. Create a board outline drawing that shows graphical representation of each component (doll) and how it is positioned on the board and in the chassis.



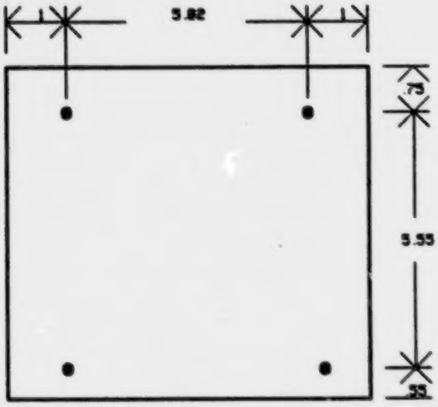
d. Check each PC board and each major component to ensure that they are positioned so that each input and output is close to the appropriate terminal on the chassis.

e. Verify that the interconnections between PC boards and to each major component can be accomplished with a minimum amount of wire.

f. Verify that user controls such as on/off are so mounted to the PC boards that they can protrude through the chassis.

g. Verify that all chassis mounted heat sinks fit properly.

h. Draw a diagram showing all dimensions for the chassis, and be sure to include the dimensions for the PC board mounting holes.



i. Mark the chassis diagram for drilling and machine work as needed.

Electronic Packaging Design
Unit 7

Assignment Sheet 1—Use Datum Dimensioning to Make a Board Outline Drawing

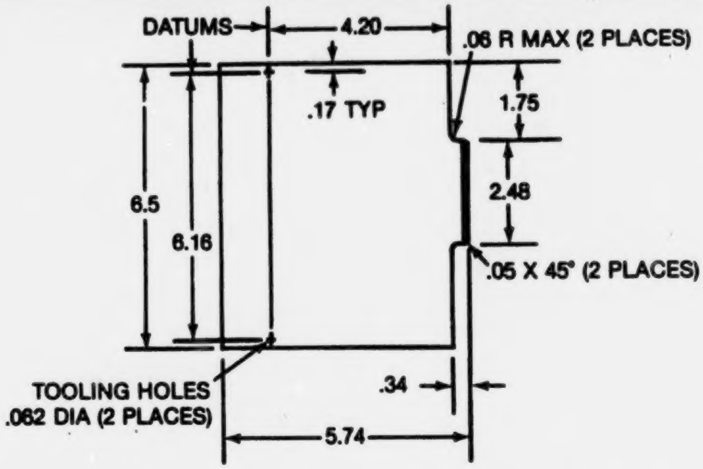
Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Board outline drawing neat and complete	______
Proper dimensions included	______
Notes included as needed	______

Directions: Use datum dimensions to make a board outline drawings of the following sketch and accompanying information. Include dimensions and appropriate notes. If one is available, use a CAD system.

CAD Alert: You'll be using lots of lines to complete your board outline, and that can easily lead to mistakes that have to be corrected. Remember that with a CAD system, mistakes can be corrected quickly, and go unnoticed.

Problem:


DATUMS
4.20
.06 R MAX (2 PLACES)
.17 TYP
1.75
2.48
6.5
6.16
.05 X 45° (2 PLACES)
TOOLING HOLES
.062 DIA (2 PLACES)
.34
5.74

1.	Tolerances on holes	+.005, −.002
2.	Bevel connector edge, both sides	.015 × 30°
3.	Material	.062 thick laminated glass epoxy, color green

Electronic Packaging Design
Unit 7

Assignment Sheet 2—Draw Component Outline "Dolls"

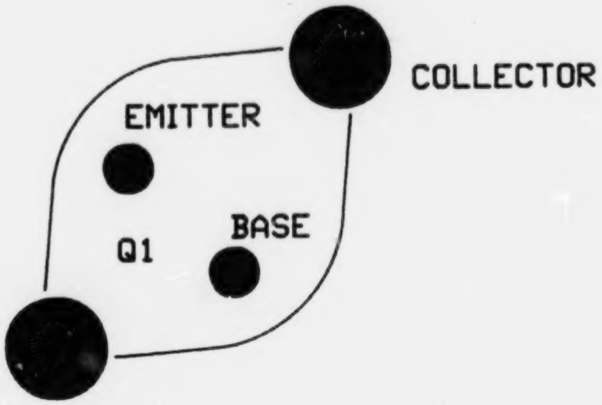
Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
"Dolls" properly drawn	______
Proper component descriptions included	______
Dimensions and sizes properly indicated	______

Directions: Use the following example as a guideline and draw component outline "dolls" on a CAD system or on appropriate media. Include description and size. If board drafting, use a template to make a 2X drawing, or, if using CAD system, pick the scale you desire.

CAD Alert: Remember that the CAD system has a symbol library to help make your task easier, and you can specify a scale that's easy to work with and then print or plot it to any scale you specify.

Example: Draw component outline 2X to a TO-3 case transistor. Label emitter, base, and collector.



Assignment Sheet 2

Problems: Draw 2X

A. ¼ watt carbon resistor

B. ½ watt carbon resistor

C. Rectifier diode

D. 10 µF 50 WVDC capacitor

E. 1000 µF 50 WVDC electrolytic capacitor

F. 8 pin DIP IC

G. 14 pin DIP IC

H. 16 pin DIP IC

I. RT 10-type P variable resistor

J. 16 lead flat pack

Electronic Packaging Design
Unit 7

Assignment Sheet 3—Draw Chassis and Package Types From Manufacturers' Catalogs

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
At least six different chassis types drawn	______
Datum-line drafting techniques used	______
Catalogs referenced dimensions	______

Directions: Use manufacturers' catalogs as supplied by your instructor, and find and list at least six different sizes and types of chassis. Obtain dimensions from the catalogs, and use datum-line techniques to make drawings of your selections. Reference your selections in the items below.

CAD Alert: When you find a symbol lacking in a symbol library, create and save the new symbol that you need. When you're engaged in a project, chances are that a symbol will be used more than once, perhaps several times.

1. Manufacturer's catalog and page number ______________________________
   Chassis type ______________________________
2. Manufacturer's catalog and page number ______________________________
   Chassis type ______________________________
3. Manufacturer's catalog and page number ______________________________
   Chassis type ______________________________
4. Manufacturer's catalog and page number ______________________________
   Chassis type ______________________________
5. Manufacturer's catalog and page number ______________________________
   Chassis type ______________________________
6. Manufacturer's catalog and page number ______________________________
   Chassis type ______________________________

Electronic Packaging Design
Unit 7

Assignment Sheet 4—Design and Draw an Electronic Package

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Datum-line drafting techniques used	______
Techniques and considerations reflected in work	______
Dimensions properly presented	______

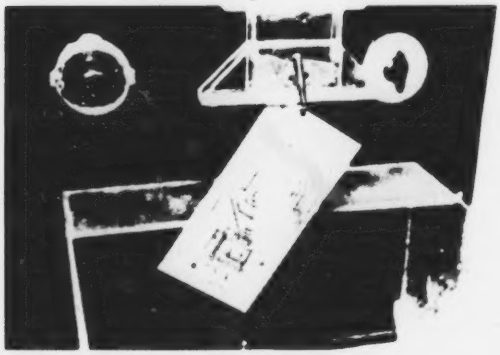
Directions: Use datum-line drafting techniques to design and draw a front panel for a stereo amplifier to meet specifications that follow. Determine appropriate placement of each listed control, and make your work reflect techniques and considerations for effective packaging.

CAD Alert: Consider every new project a prototype. This means you may be redoing parts of your drawing a second time or more. Use your CAD system to finish the job faster and make it look better.

Specifications: Front panel for the stereo is 3″ high and 11″ wide.
Holes for mounting all controls are ⅜″.

Controls in their left to right appearance on the panel are:

Balance **Treble** **Bass** **Volume** **On/Off**



PC Board Design
Unit 8

Objective Sheet

Unit Objective

After completing this unit, the student should be able to use the designated method to determine usable areas on a PC board, use the estimated method to determine PC board size, determine component density, and design a printed circuit board. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to PC board design with their correct definitions.
2. Complete statements about scaling factors and their uses in PC board design.
3. Complete statements about designated and estimated methods for determining usable space on PC boards.
4. Select true statements about considerations for determining PC board sizes.
5. Select true statements about tooling holes in PC board design.
6. Match elements of component drawings with their applications.
7. Solve problems about methods for making board outline drawings.
8. Match graphical representations with their applications in PC board design.
9. Solve problems about guidelines for designing a PC board.
10. Use the designated method to determine the total usable area of selected PC boards. (Assignment Sheet 1)

Objective Sheet

11. Use the estimated method to determine minimum PC board size. (Assignment Sheet 2)

12. Determine component density of a PC board. (Assignment Sheet 3)

13. Design a printed circuit board. (Assignment Sheet 4)

PC Board Design
Unit 8

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparencies as needed to localize the materials in this unit. Other graphic items appear with materials in the information sheet to enhance student activities.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Create a display that illustrates the steps in PC board design. Use the display throughout this unit. Emphasize the importance of each step, and the importance of completing each step in order. Skill areas: **Foundation skills, listening.**

2. Arrange for a tour of a local or area electronic drafting shop that specializes in PC Board design. Divide the class into small groups and have each group report on one given design, or the design steps they observe. Skill areas: **Group effectiveness skills, teamwork.**

3. Display several PC board layouts. Explain how having the board outline drawing with dolls placed on it aids in printed circuit layout. Discuss the elements of the design that reflect considerations for good PC board design. Tie all of this in with the procedure outlined in Objective 9. Skill areas: **Foundation skills, reading and listening.**

Resources Used in Developing This Unit

1. *903 Engineering Manual & Purchasing Guide*. Fort Worth, TX: Allied Electronics, a Subsidiary of Hall-Mark Electronics Corporation, 1993.

2. *Archer Semiconductor Reference Guide*. Fort Worth, TX: Radio Shack, a Division of Tandy Corporation, 1991.

3. Baer, Charles J. and John R. Ottaway. *Electrical and Electronic Drawing*, 5th ed. New York: McGraw-Hill, Inc., 1986.

4. Raskhodoff, Nicholas M. *Electronic Drafting and Design*, 5th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1987.

5. Reis, Ronald A. *Electronic Project Design and Fabrication*. Columbus, OH: Merrill Publishing Company, 1989.

6. Villanucci, Robert S., et al. *Electronic Techniques Shop Practices and Construction*. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1993.

Suggested Activities

Suggested Supplemental Resources

The **IPC**, The Institute for Interconnecting and Packaging Electronic Circuits, has available one of their newest technology manuals. Title *Electronic Packaging Handbook*, the handbook ranges from a general introduction to electronic packaging, system integration, and subsystem components and intraconnections, plus many more items essential to the electronic packaging industry. Order number if **IPC-PD-335**. For ordering information, call 708-677-2850 or FAX 708-677-9570 or write to:

IPC
Attn: Order Department
7380 N. Lincoln Avenue
Lincolnwood, IL 60646-1705

PC Board Design
Unit 8

Answers to Assignment Sheets

Assignment Sheet 1

A. 47.9 sq. inches

B. 56.3 sq. inches

C. 45.65 sq. inches

Assignment Sheet 2

2 IC = .549

11 RES = .302

3 CAP = .390

A_T = 1.241 sq. inches

Minimum board size = $\frac{1.241}{.80}$ = 1.55 sq. inches

Assignment Sheets 3 and 4

Evaluate according to criteria listed in the respective assignment sheets.

PC Board Design
Unit 8

Answers to Written Test

1.

a.	4	e.	13	i.	1	m.	6
b.	6	f.	10	j.	5	n.	7
c.	12	g.	9	k.	8		
d.	2	h.	11	l.	14		

2. a. Not
   b. 4:1 or 4X
   c. 4X. 4X
   d. 1:1 or 1X, to 2X or 4X
   e. Error

3. a. Designated
   b. Designated
   c. Estimated
   d. Estimated

4. a, b, d, e, f

5. a

6.

a.	2	d.	1
b.	4	e.	5
c.	6	f.	3

7. a. (3)
   b. (2)

8. a. 3
   b. 1
   c. 2

9. a. (3)
   b. (1)

PC Board Design
Unit 8

Written Test

Name ______________________ Date ____________ Score __________

1. Match the terms on the right with their correct definitions.

_____a. The drawing of the physical shape of a PC board (or boards) that is to be mounted in a package

_____b. The container used for mounting a PC board

_____c. Any part connected or mounted to a PC board

_____d. Number of components per given area

_____e. A drawing that shows the contour and overall dimensions of components inside an outline

_____f. An outline of a component usually drawn 2X or 4X its actual size

_____g. A metal configuration used to dissipate heat generated by electronic devices

_____h. The conductor or copper side of a PC board

_____i. Holes used for mounting the PC board to the chassis or package

_____j. Changes documented on a drawing

_____k. Holes used for the registration of a PC board or artwork

_____l. The height of components relative to the surface of the PC board

_____m. The area on a PC board that cannot be used for placement of components or traces

_____n. A CAD system command that makes an object appear larger on a computer display

1. Mounting holes
2. Component density
3. Unusable area
4. Board outline
5. Revisions
6. Chassis
7. Zoom-in
8. Tooling holes
9. Heat sink
10. Doll
11. Layer
12. Component
13. Component outline drawing
14. Topographical

Written Test

2. Complete statements about scaling factors and their uses in PC board design. Circle the material that best completes each of the following statements.

   a. A scaling factor designates the size of the drawing of a PC board, (**and also**) (**not**) the actual size of the board.

   b. In PC board design, the three commonly used scaling factors are 1:1 or 1X; 2:1 or 2X, and (**3:1 or 3X**) (**4:1 or 4X**).

   c. With manual drafting techniques, use the 2X or (**3X**) (**4X**) scaling factor, and templates for most major components are available for board work in the 2X and (**3X scales**) (**4X scales**).

   d. When using a CAD system, draw on the (**2:1 or 2X**) (**1:1 or 1X**) scale because when the drawing is finished it can be plotted (**back to 1X or up to 4X**) (**to 2X or 4X**).

   e. When drawing complex objects on a CAD system, use the zoom-in command to increase the size of the drawing area to make drawing easier and to eliminate the chances for (**duplication**) (**error**).

3. Complete statements about designated and estimated methods for determining usable space on PC boards. Circle the material that best completes each of the following statements.

   a. Since standard size PC boards are used in many applications, use the (**designated**) (**standard**) method to determine usable space on the board.

   b. To apply the (**designated**) (**standard**) method, subtract (**the usable area**) (**25%**) from the total area of the PC board.

   c. When a standard PC board size is not specified, use the (**estimated**) (**approximate**) method to determine usable space on the board.

   d. To apply the (**approximate**) (**estimated**) method, compute the total square area of all components, and then add (**25%**) (**20%**) to determine board size.

4. Select true statements about considerations for determining PC board sizes. Place an "X" beside each true statement.

   ______a. Since the cost of PC boards increase with their size, size and package limitations should be a prime consideration because large boards have a tendency to warp and bow.

   ______b. Since the cost of production rises sharply with the number of layers, use single or double layers when possible to minimize cost and simplify the design process.

______c. Generally, only 50% of a PC board area is usable area, but board size may be restricted because of package size, connectors, or heat sinks.

______d. Mount components at least 0.10″ from the edge of the PC board, and pay careful attention to topographical aspects, how far components will be above the chassis.

______e. The type of connector may dictate its location on the board.

______f. Examine packaging specifications to make sure cutout requirements do not interfere with packaging.

5. Select true statements about tooling holes in PC board design. Place an "X" beside each true statement.

______a. Since tooling holes are used as a reference for manufacturing, and connectors are often indexed to tooling holes, respect guidelines for their applications.

______b. Locate tooling holes in upper corners of a PC board, unless otherwise specified.

______c. Locate tooling holes no closer than 1″ from the edge of a PC board.

______d. Make the diameter of tooling holes .25″ unless otherwise specified.

6. Match elements of component drawings with their applications. Place the number beside the element in the blank beside the description of its application.

______a. Information on component drawings comes from vendor drawings, catalogs, and standards

______b. Must be specified with component drawing dimensions

______c. Must be specified so that drill hole size and pad size can be determined

______d. Locations must be illustrated

______e. Include instructions for mounting and any special handling required

______f. Frequently included to indicate the interchangeability of parts between vendors

1. Indexing tabs
2. Sources
3. Cross references
4. Body size
5. Electrical characteristics
6. Maximum lead diameter

Written Test

7. Solve problems about methods for making board outline drawings. Circle the number beside the statement that best solves each of the following problems.

   a. You know you're going to have to do a board outline drawing by hand. You need dimensions to go with your component drawings. To solve your problem, you should:

      (1) Measure real components and write the dimensions down.

      (2) Use typical dimensions and change them later if you have to.

      (3) Use dimensions from the component drawings themselves.

   b. You are working on a CAD system to complete a board outline, but you run into a specified component that you cannot find in your CAD library. To solve your problem, you should:

      (1) Send a note to the engineer who made the specification and request more information.

      (2) Use vendor's dimensions, create a doll, and save it for future use.

      (3) Reserve a space for the component and put it in at a later date when you have more information.

8. Match graphical representations with their applications in PC board design. Place the number beside the graphical representation in the blank beside the description of its application.

______a. Used as a boundary or border to represent the outline of the PC board

______b. Use to indicate where components are located within board outline drawings

______c. Used to show the height of components above the chassis of the PC board

1. Component placement drawings
2. Topographical layout
3. Board outline drawings

Written Test

9. Solve problems about guidelines for designing a PC board. Circle the number of the statement that best solves each of the following problems.

   a. You've been asked to check a PC board design that another drafter has completed. You note that there are several components with large numbers of connections between them that are placed at opposite edges of the board. To correct the problem, you should:

      (1) Make a notation and send it back to the other student.

      (2) Suggest ways the board could be drawn differently.

      (3) Move components around until the components with large numbers of connections between them are next to each other.

   b. You're at a point in your PC board design where you have to decide whether to place a three-lead transistor or a two-lead diode on your board. To solve your problem, you should:

      (1) Place components with three leads or more on the board before components with two leads.

      (2) Place components with two leads on the board before you place components with three leads or more.

      (3) Place components in any order as long as they clear edge connectors by a minimum of .10".

***Permission to duplicate this test is granted.**

PC Board Design
Unit 8

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Use the Designated Method to Determine Total Usable Area of Selected PC Boards Rating _____

Comments: ____

____

Assignment Sheet 2—Use the Estimated Method to Determine Minimum Board Size Rating _____

Comments: ____

____

Assignment Sheet 3—Determine Component Density Rating _____

Comments: ____

____

Assignment Sheet 4—Design a Printed Circuit Board Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

*Permission to duplicate this form is granted.

PC Board Design
Unit 8

Information Sheet

1. **Terms and definitions**

    a. **Board outline** — The drawing of the physical shape of a PC board (or boards) that is to be mounted in a package

    b. **Chassis** — The container used for mounting a PC board

    c. **Component** — Any part connected or mounted to a PC board

    d. **Component density** — Number of components per given area

    e. **Component outline drawing** — A drawing that shows the contour and overall dimensions of components inside an outline

    f. **Doll** — An outline of a component usually drawn 2X or 4X its actual size

    g. **Heat sink** — A metal configuration used to dissipate heat generated by electronic devices

    h. **Layer** — The conductor or copper side of a PC board

    Note: A PC board may have one or many layers.

    i. **Mounting holes** — Holes used for mounting the PC board to the chassis or package

    j. **Revisions** — Changes documented on a drawing

    k. **Tooling holes** — Holes used for the registration of a PC board or artwork

    l. **Topographical** — The height of components relative to the surface of the PC board

    m. **Unusable area** — The area on a PC board that cannot be used for placement of components or traces

    n. **Zoom-in** — A CAD system command that makes an object appear larger on a computer display

Information Sheet

2. Scaling factors and their uses in PC board design

a. A scaling factor designates the size of the drawing of a PC board, not the actual size of the board.

b. In PC board design, the three commonly used scaling factors are 1:1 or 1X; 2:1 or 2X, and 4:1 or 4X.

c. With manual drafting techniques, use the 2X or 4X scaling factor, and templates for most major components are available for board work in the 2X and 4X scales.

d. When using a CAD system, draw on the 1:1 or 1X scale because when the drawing is finished it can be plotted to 2X or 4X.

e. When drawing complex objects on a CAD system, use the zoom-in command to increase the size of the drawing area to make drawing easier and to eliminate the chances for error.

3. Designated and estimated methods for determining usable space on PC boards

a. Since standard size PC boards are used in many applications, use the designated method to determine usable space on the board.

b. To apply the designated method, subtract the usable area from the total area of the PC board.

c. When a standard PC board size is not specified, use the estimated method to determine usable space on the board.

d. To apply the estimated method, compute the total square area of all components, and then add 20% to determine board size.

4. Considerations for determining PC board sizes

a. Since the cost of PC boards increase with their size, size and package limitations should be a prime consideration because large boards have a tendency to warp and bow.

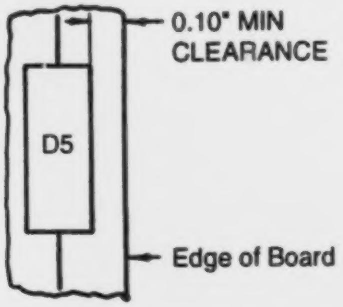
b. Since the cost of production rises sharply with the number of layers, use single or double layers when possible to minimize cost and simplify the design process.

Information Sheet

c. Generally, 80% of a PC board area is usable area, but board size may be restricted because of package size, connectors, or heat sinks.

Example: On boards with a large number of edge connectors and terminal connections, the usable board area is reduced significantly.

d. Mount components at least 0.10" from the edge of the PC board, and pay careful attention to topographical aspects, how far components will be above the chassis.



Component to Board Edge

e. The type of connector may dictate its location on the board.

f. Examine packaging specifications to make sure cutout requirements do not interfere with packaging.

5. Guidelines for tooling holes in PC board design

a. Since tooling holes are used as a reference for manufacturing, and connectors are often indexed to tooling holes, respect guidelines for their applications.

b. Locate tooling holes in diagonal corners of a PC board, unless otherwise specified.

c. Locate tooling holes no closer than 0.10" from the edge of a PC board.

d. Make the diameter of tooling holes 0.062" unless otherwise specified.

Information Sheet

6. **Elements of component drawings and their applications**

   a. **Sources** — Information on component drawings comes from vendor drawings, catalogs, and standards

   b. **Body size** — Must be specified with component drawing dimensions

   c. **Maximum lead diameter** — Must be specified so that drill hole size and pad size can be determined

   d. **Indexing tabs** — Locations must be illustrated

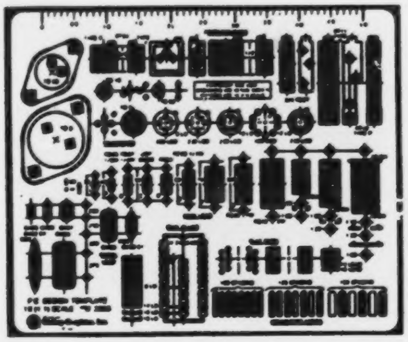
   e. **Electrical characteristics** — Include instructions for mounting and any special handling required

   f. **Cross references** — Frequently included to indicate the interchangeability of parts between vendors

7. **Methods for making board outline drawings**

   a. Although the process is time consuming, you can use dimensions from component drawings to draw components in the board outline drawing.

   b. You can draw board outlines with 2X or 4X templates fairly fast, but changes are time consuming.



PC Design

Courtesy Bishop Graphics

   c. With board drafting, beginners find that using component outline dolls makes things easier because they can move the dolls around within the board outline.

Information Sheet

d. With a CAD system, board outline symbols are usually available from a component outline library, and they can be easily moved around with no need for erasures or redrawings.

e. When a component can't be found in a library, use the vendor's dimensions to create a doll with the CAD system, and then save it for future use.

8. **Graphical representations and their applications in PC board design**

a. **Board outline drawings** — Used as a boundary or border to represent the outline of the PC board

b. **Component placement drawings** — Use to indicate where components are located within board outline drawings

c. **Topographical layout** — Used to show the height of components above the chassis of the PC board

9. **Guidelines for designing a PC board**

a. Use the determined method to size the PC board, if a standard board is specified, or use the estimated method to determine minimum board size if a standard board is not specified.

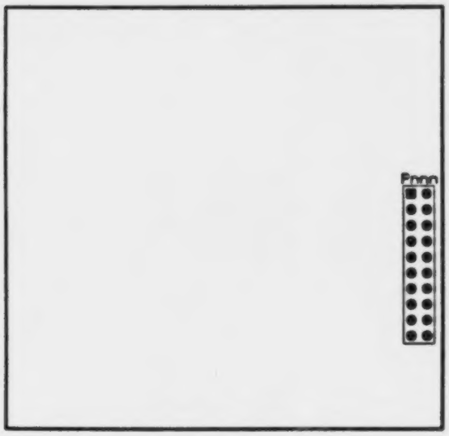
b. If you use a standard board size, draw the board outline from the standard board size dimensions listed in the vendor catalog.

CAD Alert: Remember that some standard board sizes may be available in the symbol library of your CAD system, and that you can create standard board outlines on your CAD system and save them for future use.

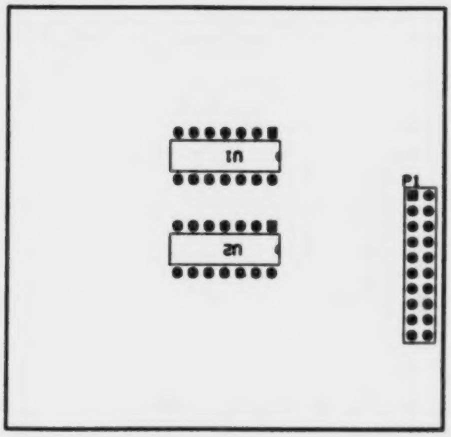
c. If you do not use a standard board size, draw a board outline that is 20% larger than the square area of all the components that will be used, and take into consideration connectors, cutouts, and other special requirements.

Information Sheet

d. Place the edge card connectors on the board outline drawing, and remember that these are often available in a CAD symbols library.



e. As you place ICs and other large components on the board outline, place components with large numbers of connections between them next to each other.



Board outline with dolls for two ICs and a transformer placed

f. Move dolls as needed so that components are spaced evenly across the board.

Information Sheet

g. Place all transistors and other components with three or more leads onto the board outline.

Note: Information about minimum spacing between components and maximum density would be available on an Engineer's sketch.

h. Place all resistors, diodes, capacitors, and other components with two leads onto the board outline, and move components as you need to as you add more components to the board outline.

CAD Alert: Moving components around with a CAD system is easy. Simply use the "Move" command.

i. Check off each component on the BOM (bill of materials) to be sure that components have been placed on the board.

PARTS LIST

BRYTEK INC	CONTRACT NO TWO	DOCUMENT NUMBER 4C	REVISION 1
TITLE DIGITAL INTERFACE	AUTHENTICATION	REV AUTH NO	SHEET 1 OF 1

ITEM NO	QTY REQD			CODE IDENT	BISHOP REFERENCE NO	PART NUMBER	DESCRIPTION
1			1			AX25C	PRINTED WIRING BOARD
2			2		C1	CK05CW12	CAPACITOR, 1 uF, 20V
3			1		C2	CSR13E334	CAPACITOR, 33 uF,10V
4			5		CR1-CR6	1N916	SEMI-CONDUCTOR DEVICE, DIODE
5			1		U1	7401	IC QUAD 2-INPUT POS NAND GATES WITH OPEN COL
6			1		U2	7490	IC DECADE COUNTER
7			1		U3	7442	IC 4 TO 10 LINE DECODER
8			5		U4, U5, U6, U7 U8	7400P	IC QUAD 2-INPUT POS NAND GATES
9			4		R1,R48,R56,R67	89PR20M	RESISTOR, VARIABLE, 20M, 89PR
10			1		R2	89PR500	RESISTOR, VARIABLE, 500 OHM, 89PR
11			6		R3, R4, R11, R12, R19, R20	PCR07G53J	RESISTOR, CARBON COMP, 500 OHM, 1/2W, 5%
12			9		R5, R6, R7, R13, R14, R15, R21, R22, R23	PCR07G52J	RESISTOR, CARBON COMP., 500 OHM, 1/2W, 5%
13			5		R8, R16, R24	PCR07G34J	RESISTOR, CARBON COMP., 30K, 1/2W, 5%
14			3		R9, R17, R25	PCR07G23J	RESISTOR, CARBON COMP., 2K, 1/2W, 5%
15			3		R10, R18, R26	PCR07G13J	RESISTOR, CARBON COMP., 1K, 1/2W, 5%
16			1		Q1	2M3819	TRANSISTOR, FET
17			6		Q2, Q3, Q4, Q5, Q6, Q7	2M2102	TRANSISTOR, NPN
18			1		PLT1		FINAL SCHEMATIC PLOT
19			2		DPLT1		DUPLICATE SCHEMATIC

Information Sheet

j. Sketch a topographical of the PC board.

k. Check the topographical against the chassis dimensions to be sure the board will fit the chassis.

   Note: Rearranging components may be required again at this point in order to make all components fit the chassis.

l. If you're board drafting, secure the dolls to the board outline drawing with tape or glue, or if you have a CAD system, print a plot of the board outline.

   Note: Your drawing or print will be used to create a PC board layout of the PC board.

m. Make revisions required, and document them neatly on the drawing.

PC Board Design
Unit 8

Assignment Sheet 1—Use the Designated Method to Determine Total Usable Area of Selected PC Boards

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Designated method used to arrive at answer	______
Edge connectors and border areas properly figured	______
Edge connectors properly determined	______

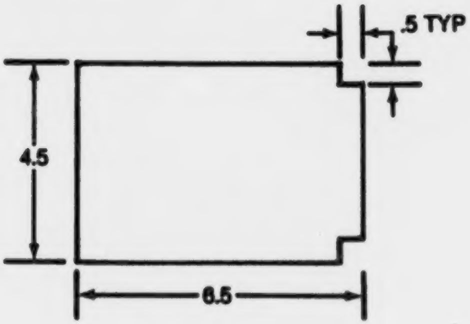
Directions: Determine the total usable areas of the printed circuit boards in the following illustrations. Review the general information about the designated method before you start your assignment.

General Information:

1. Standard size boards are used in some cases due to standard mounting configurations
2. Subtract unusable area (edge connectors and border area) from total area to get usable area
3. Use .10″ minimum for border width
4. Edge connector cut-outs may vary

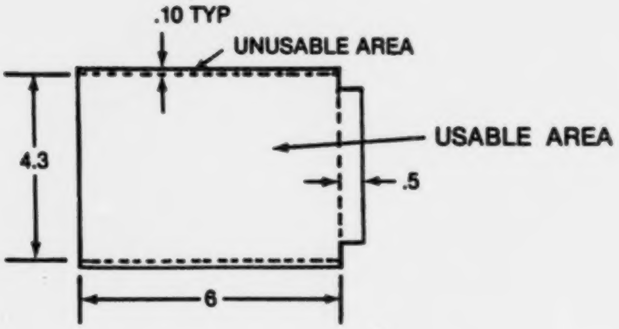
Example:

1. Given: Standard size board 4.5″ × 6.5″



Assignment Sheet 1

2. Solution using appropriate formulas:



a. Area of board (A_1) = Length (L) × width (W)

$A_1 = L \times W$

$A_1 = 6.5 \times 4.5$

$A_1 = 29.25$ sq. inches

b. Area of cutouts such as corner notches (2 shown in example)

$A_2 = 2(L \times W)$

$A_2 = 2(.5 \times .5)$

$A_2 = .50$ sq. inches

c. Total board area (A_T) = Area of board (A_1) – area of cutouts (A_2)

$A_T = A_1 - A_2$

$A_T = 29.25 - .50$

$A_T = 28.75$ sq. inches

d. Area of connector (A_C) = Length × width

$A_C = L \times W$

$A_C = 3.5 \times 5$

$A_C = 1.75$ sq. inches

Assignment Sheet 1

e. Border area (A_B) = Length × width

$A_B = L \times W$

$A_B = 2(6 \times .1) + (4.3 \times .1)$

$A_B = 1.63$ sq. inches

f. Unusable area (A_{UN}) = Area of connectors (A_C) + border area (A_B)

$A_{UN} = A_C + A_B$

$A_{UN} = 1.75 + 1.63$

$A_{UN} = 3.38$ sq. inches

g. Total usable area A_U = Total board area (A_T) – unusable area (A_{UN})

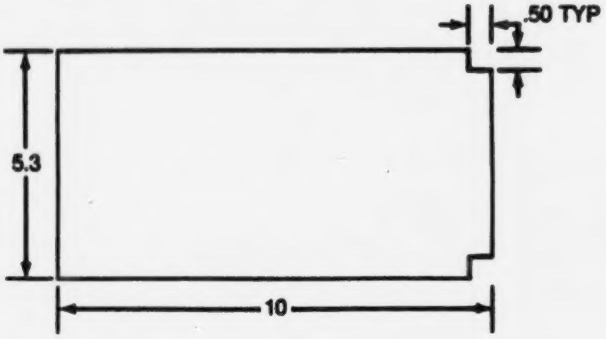
$A_U = A_T - A_{UN}$

$A_U = 28.75 - 3.38$

$A_U = 25.37$ sq. inches

Problems:

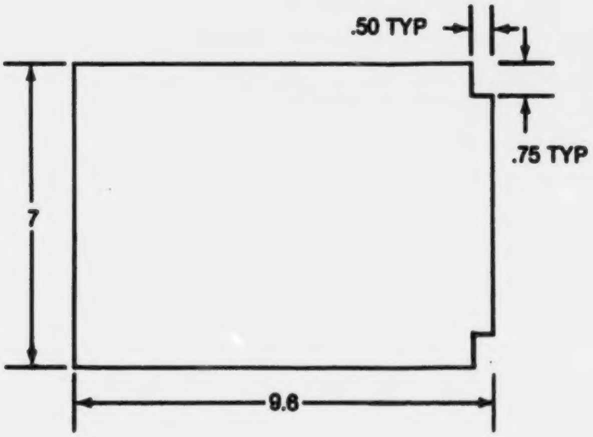
A. Given: Use .1″ for unusable border width



Total usable area ______________________________

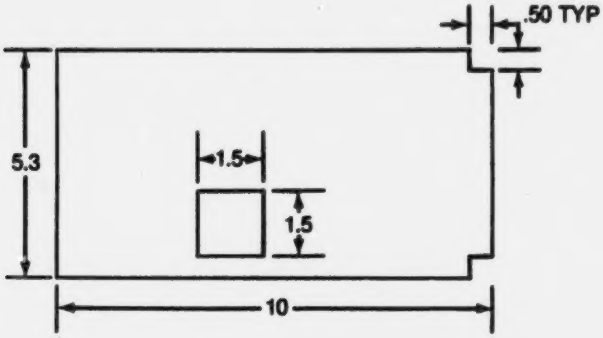
Assignment Sheet 1

B. Given: Use .30″ for unusable border width


.50 TYP
.75 TYP
7
9.6

Total usable area ______________________________

C. Given: Use .20″ for unusable border width


.50 TYP
5.3
1.5
1.5
10

Total usable area ______________________________

PC Board Design
Unit 8

Assignment Sheet 2—Use the Estimated Method to Determine Minimum Board Size

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Estimated method used to arrive at answer	______
Components and sizes listed for reference	______
All board areas used in determination	______

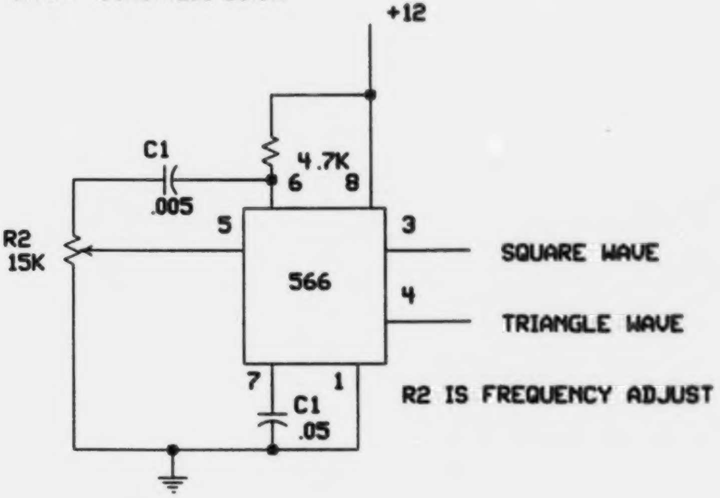
Directions: Use the estimated method to determine the board sizes in the problems that follow. Review the general information about the estimated method before you start your assignment.

General information for computations:

1. Compute total square area of all components
2. Determine minimum board size (MBS) based on 80% area of components on usable area of board

Example:

1. Given: Schematic below


+12
C1
.005
4.7K
6
8
5
3
R2
15K
566
SQUARE WAVE
4
TRIANGLE WAVE
7
1
C1
.05
R2 IS FREQUENCY ADJUST

Assignment Sheet 2

2. Solution:

a. Determine total area for components

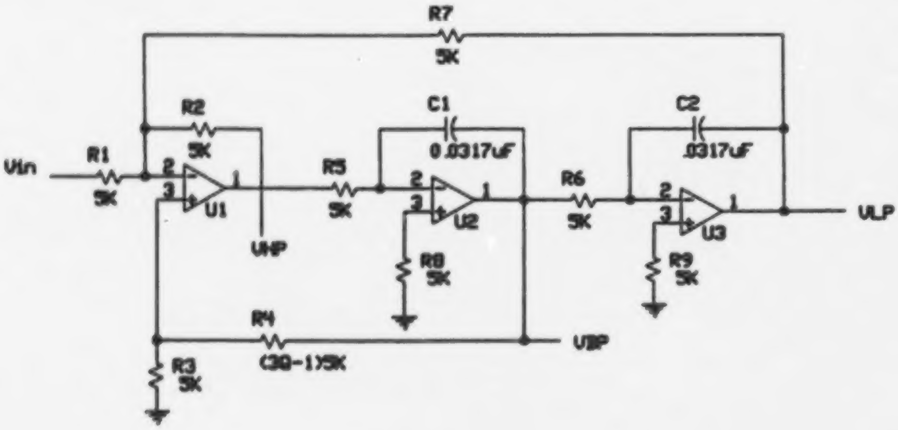
QUANTITY	DESCRIPTION (From Schematic)	SIZE (From Manufacturer)	AREA
1	8 pin DIP	= .395 × .395	= .156
2	Capacitors	= 2(.55 × .236)	= .260
1	Resistor	= .098 × .28	= .027
1	POT-Trimmer	= .16 × .75	= .120
	Total area for components		= .563

b. Determine minimum board size (MBS) based on 80% of components

$$\text{MBS} = \frac{\text{Total area for components } (A_T)}{80\%}$$

$$\text{MBS} = \frac{A_T}{.80} = \frac{.563}{.80} = .70 \text{ sq. inches}$$

Problem: Complete the following chart and determine the minimum board size using the following schematic.


R7
5K
R2
5K
C1
0.0317uF
C2
.0317uF
Vin
R1
5K
2
3
1
U1
R5
5K
2
3
1
U2
R6
5K
2
3
1
U3
VLP
VHP
R8
5K
R9
5K
R4
(3Q-1)5K
VBP
R3
5K

STATE-VARIABLE FILTER

Assignment Sheet 2

QUANTITY	DESCRIPTION	SIZE	AREA

Minimum board size ____________________________

PC Board Design
Unit 8

Assignment Sheet 3—Determine Component Density

Name ______________________________ Overall Rating ________

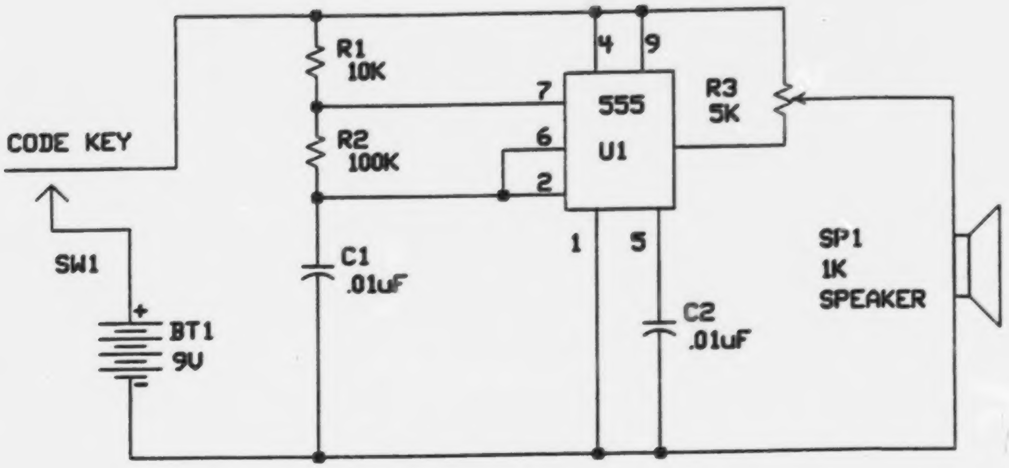
Evaluation Criteria	**Rating**
Board outline properly drawn	______
Component dolls constructed for each part	______
Dolls evenly distributed over board outline	______

Directions: Use the schematic sketch and the sketch of the board outline which follow as a guideline to (1) draw a board outline, (2) construct component dolls for each part, and (3) evenly distribute dolls over the board outline. If you use manual drafting techniques, draw at a 2X scale, and tape the dolls in place after labeling and final arrangement. If you're using a CAD system, draw at a 1X scale, and plot at a 2X scale after you complete the drawing.

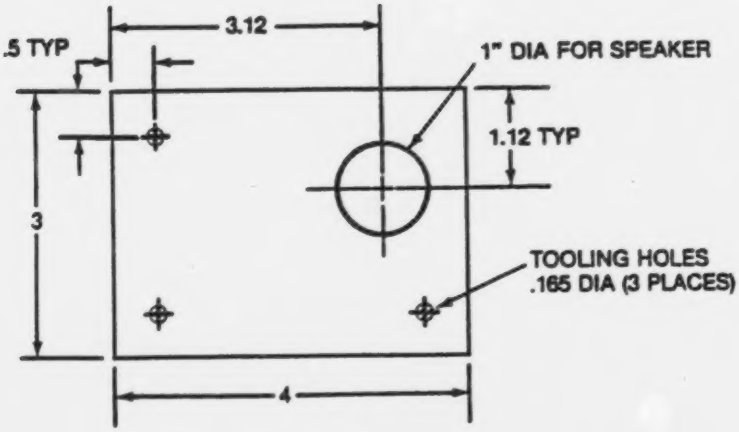
CAD Alert: With a CAD system, these kinds of drawings are easier to make because replotting is easy. With CAD you not only save valuable time, the drawings are always neat after changes have been made.

Additional information: For parts less than .3″ wide, add adjacent component widths together and divide by two to obtain clearance separation between parts. For parts greater than .3″ wide, allow approximately .3″ separation between the parts.

Assignment Sheet 3


CODE KEY
SW1
BT1
9V
R1
10K
R2
100K
C1
.01uF
7
6
2
4
9
1
5
555
U1
R3
5K
C2
.01uF
SP1
1K
SPEAKER

MORSE CODE PRACTICE OSCILLATOR


3.12
.5 TYP
1" DIA FOR SPEAKER
1.12 TYP
3
TOOLING HOLES
.165 DIA (3 PLACES)
4

Board Outline Sketch

PC Board Design
Unit 8

Assignment Sheet 4—Design a Printed Circuit Board

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Proper board outline sizes used	______
2X used for manual, 1X for CAD	______
Dimensions taken from vendors catalogs	______

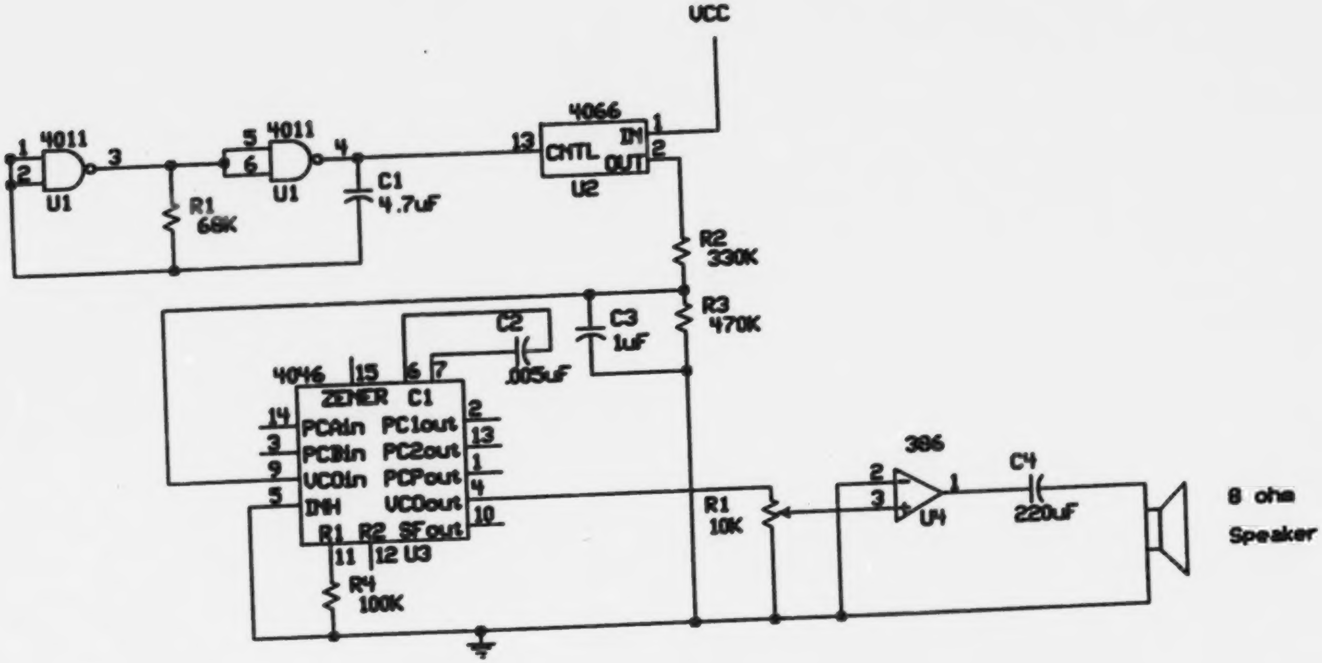
Directions: Use the schematic diagram below to design a printed circuit board. Reference the general information before you start your assignment.

CAD Alert: Use your symbol library as needed to help make your work easier, especially when you start making dolls. It's suggested that you use a 1X scale when working with CAD, but be sure to make your final plot 2X.

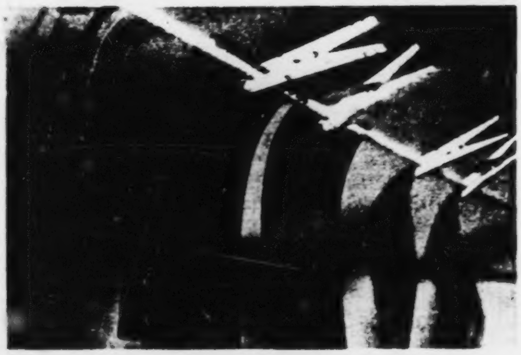
General information:

1. Use a board outline of 3″ × 6″ with 0.5″ × 0.5″ notches removed from each corner.
2. If using manual techniques and a drafting board, make the board outline and the dolls 2X.
3. If using a CAD system, make the board outline and dolls 1X, but make your final plot 2X.
4. Obtain dimensions as needed from vendor catalogs.

Assignment Sheet 4


VCC
4011
1
2
3
U1
5
4011
6
4
U1
R1
68K
C1
4.7uF
4066
13
CNTL
IN
OUT
1
2
U2
R2
330K
R3
470K
C2
.005uF
C3
1uF
4046
15
6
7
ZENER
C1
14
PCAin
3
PCBin
9
VCOin
5
INH
PC1out
2
PC2out
13
PCPout
1
VCOout
4
SFout
10
R1
R2
11
12
U3
R4
100K
R1
10K
386
2
3
1
U4
C4
220uF
8 ohm
Speaker

ALARM AND AMP



PC Board Layout
Unit 9

Objective Sheet

Unit Objective

After completing this unit, the student should be able to print pc board layout symbols from a CAD library, create new symbols for common components, and construct and plot finished artwork for a PC Board. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to pc board layout with their correct definitions.
2. Match pc board layout requirements with their functions.
3. Select true statements about component information required for pc board layout.
4. Select true statements about hardware and software requirements for pc board layout.
5. Solve problems related to other considerations for CAD pc board layout.
6. Select true statements about grid applications and spacing.
7. Solve problems about common layout scales.
8. Use a reference to answer questions about selecting trace widths.
9. Complete statements about guidelines for spacing traces.
10. Complete statements about guidelines for trace layout.
11. Differentiate between types of terminal holes and their functions.

Objective Sheet

12. Use a reference to answer questions about determining minimum terminal/pad size.

13. Complete statements about grounding methods and their applications.

14. Complete statements about busing techniques.

15. Select true statements about shielding considerations.

16. Select true statements about shielding techniques.

17. Select true statements about peripheral orientation.

18. Solve problems related to laying out a pc board on a CAD system.

19. Print available symbols from a CAD system pc board library and create new symbols for common components. (Assignment Sheet 1)

20. Construct a layout for a pc board and plot the finished artwork. (Assignment Sheet 2)

PC Board Layout
Unit 9

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan enrichment of exceptional students as well as accommodation of special needs students.

4. Add graphic materials or overhead transparencies as needed. Most of the graphics in this unit are included with materials in the information sheets to enhance graphic impact of the materials.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

Suggested Activities

14. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignment or job sheets.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Have a variety of pc boards available to demonstrate various elements of layout as they are presented in this unit of instruction. Concentrate on components placement and traces as you show the boards to students. Skill areas: **Learning skills, learning to learn.**

2. Assign a single board to groups of two or three students. Have them examine the board for component placement, trace width, pad size, and edge orientation. Then, have the groups physically demonstrate their findings to the class. Skill areas: **Group effectiveness skills, teamwork.**

3. Enhance Objectives 6 and 7 with a physical demonstration of grid applications. Show students 1X, 2X, and 4X artwork an show how the different sizes serve specific purposes. Skill areas: **Learning skills, learning to learn.**

4. Arrange for an electronic engineer with pc board layout experience to talk to the class about the pc board industry and what its future holds for capable drafters. Skill areas: **Foundation skills, listening.**

5. Find a pc board layout facility or an electronic drafting shop in your city or area, and arrange for the students to visit. Divide the class into teams before the visit, and have them take notes and give team reports about what they saw during the visit. Skill areas: **Group effectiveness skills, teamwork.**

6. Use Objective 18 to demonstrate the importance of doing things by the book. Impress upon students the importance of knowing the limits of both the hardware and software they are using. Try to demonstrate the difference between drafting software in general and software designed specifically for pc board layout. Skill areas: **Learning skills, learning to learn.**

Suggested Activities

Resources Used in Developing This Unit

1. Byers, T. J. *Printed Circuit Board Design with Computers.* NY: McGraw-Hill, 1991.
2. Coombs, Clyde F. *Printed Circuits, Vol. 1: Engineering and Fundamentals.* NY: McGraw-Hill, 1990.
3. *Dictionary of Electrical and Electronic Terms, ANSI/IEEE 100-1988.* NY: American National Standards Institute, 1988.
4. Ginberg, Gerald. *Printed Circuits Design.* NY: McGraw-Hill, 1991.
5. McClain, Gerald R. and Neal A. Wilson. *Electronic Drafting.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1983.

Suggested Supplemental Resources

The **IPC**, The Institute for Interconnecting and Packaging Electronic Circuits, has available one of their newest technology manuals. title *Electronic Packaging Handbook*, the handbook ranges from a general introduction to electronic packaging, system integration, and subsystem components and intraconnections, plus many more items essential to the electronic packaging industry. Order number is **IPC-PD-335**. For ordering information, call 708-677-2850 or FAX 708-677-9570. To place orders write to:

IPC
Attn: Order Department
7380 N. Lincoln Avenue
Lincolnwood, IL 60646-1705

The Electronic Industries Association EIA, JEDEC, and TIA Standards and Engineering Specifications 1994 Catalog is available from Global Engineering. These standards and related publications are widely adopted by industries around the world. The materials facilitate the manufacture of electronic components and also provide optimum routing for their procurement. For a free catalog, call Global Engineering at 303-792-2181, or write:

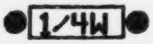
Global Engineering Documents
15 Inverness Way East
Denver, CO 80112

PC Board Layout
Unit 9

Answers to Assignment Sheets

Assignment Sheet 1

A. 1.



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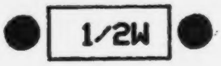

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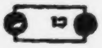

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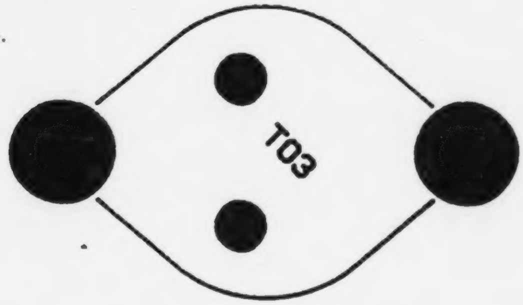
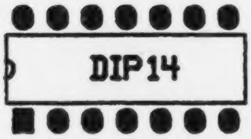
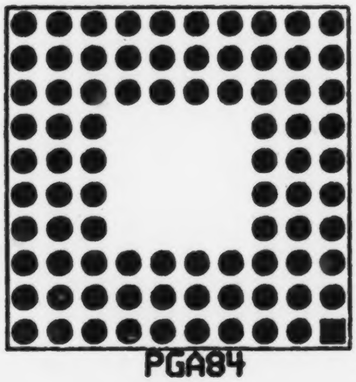


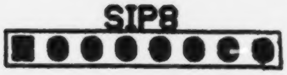
5.



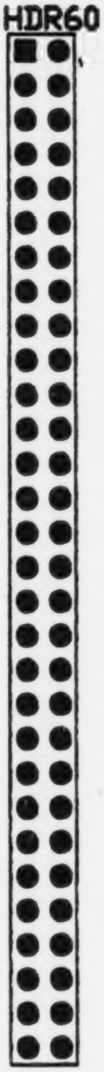
6.



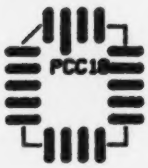
7.



8.

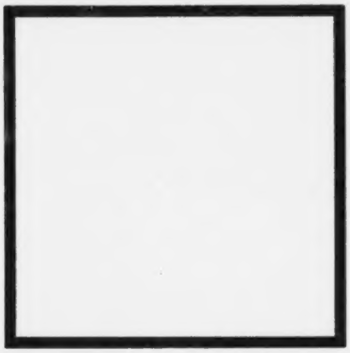


9.

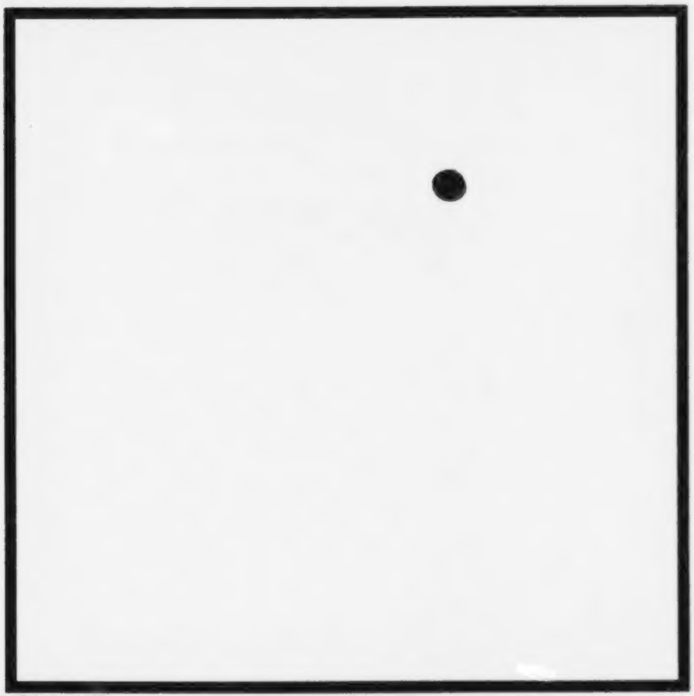


Answers to Assignment Sheets

B. 1.



2. (Pad location may vary)



Assignment Sheet 2

Evaluate according to criteria written in the assignment sheet. Student answers will vary with type of CAD system and software used.

PC Board Layout
Unit 9

Answers to Written Test

1. a. 7
   b. 13
   c. 3
   d. 10
   e. 5
   f. 15
   g. 12
   h. 14
   i. 8
   j. 16
   k. 4
   l. 11
   m. 1
   n. 17
   o. 9
   p. 2
   q. 6

2. a. 2
   b. 4
   c. 1
   d. 3

3. a, b, d, e

4. a

5. a. (3)
   b. (3)

6. a, b

7. a. (2)
   b. (1)

8. a. 0.070"
   b. 0.100"

9. a. Signal
   b. Power and ground
   c. 0.02"

10. a. Parallel
    b. Perpendicular
    c. Color schemes
    d. Short
    e. The edge of the board or any mounting hardware

11. a. U
    b. P

Answers to Written Test

12. a. .093"
    b. No. Never design a pad below the specified minimum.
    c. 19, 17

13. a. Digital
    b. Analog
    c. Multiple

14. a. ICs
    b. Density

15. a, b

16. a, c, d

17. a

18. a. (2)
    b. (3)

PC Board Layout
Unit 9

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. A diagram that shows groups of components in a general relationship

______b. An itemized list of parts included with an assembly drawing

______c. A low resolution plot of a pc board used to save time plotting, but not good for final artwork

______d. A computer with keyboard, monitor display, a hard or floppy disk for data storage, a device for printing or plotting information, and an operating system and software designed to execute input from an operator

______e. A medium that passes electrical inputs from one point to another

______f. Computer programs designed especially for developing schematics, ladder diagrams, master patterns, marking drawings, and assembly drawings for use in the electronic industry

______g. Connector made on the edge of a pc board

______h. Interference caused by magnetism created by current flow in a conductor

______i. The pattern of dots displayed on a computer screen so that a drafter can relate the pattern size and use it as the equivalent of a scale

1. Schematic diagram
2. Thermal sensitivity
3. Checkplot
4. Multiplayer board
5. Conductor
6. Trace width
7. Block diagram
8. Grid
9. Test point
10. Computer system
11. Pen plotter
12. Edge connector
13. BOM
14. Electromagnetic interference
15. Drafting software
16. Layers
17. Snap

Written Test

______j. The single layers of a pc board

______k. A pc board with more than one layer of foil

______l. An output device used to print a precision copy of a drawing created on a CAD system

______m. A wiring diagram showing all components of an electrical circuit and how they are connected, but the diagram does not show true size, shape, or placement

______n. A command that causes the curser on a CAD system to snap to the nearest grid point

______o. The point on a pc board where a special connector is placed so that a test instrument can be easily connected

______p. The amount of degradation in component performance when the component is subjected to temperature change

______q. The width of a conductor that interconnects components on a pc board

2. Match PC Board layout requirements with their functions. Place the number of the requirement in the blank beside the description of the functions.

______a. Used to determine component connections

______b. Used to determine which components should be grouped together

______c. Used to identify each component

______d. Used to determine other pc board requirements such as clearances, tooling holes, keep-out areas, and physical board size

1. BOM
2. Schematic/logic diagram
3. Specifications/ mechanicals
4. Block diagram

Written Test

3. Select true statements about component information required for pc board layout. Place an "X" beside each true statement.

   ______a. Determine the size of all components.

   ______b. Determine the lead pattern and lead sizes for each component.

   ______c. Determine the maximum spacing between components.

   ______d. Determine special mounting data such as heat sink placement.

   ______e. Determine required terminal area types.

   ______f. Review the basic electrical and thermal limitations for each component.

4. Select true statements about hardware and software requirements for pc board layout. Place an "X" beside each true statement.

   ______a. The basic hardware requirements is a computer system with a sufficient amount of memory and a high speed operating system.

   ______b. Another essential hardware requirement is a good dot-matrix printer.

   ______c. Software means any software that can be modified for drafting purposes.

5. Solve problems about other considerations for CAD pc board layout. Circle the number beside the statement that best solves each of the following problems.

   a. You have a DIP component in a pc board design, and the manufacturer's data book indicates this component generates a lot of heat. A coworker tells you to play it safe and try to replace the DIP, but to solve the problem, you could:

      (1) Put a heat sink around the component.

      (2) Keep all traces as far from the component as possible.

      (3) Place the component as far away as you can from other components that might be affected by the heat.

b. You have been given a pc board design that has a test point at an interior location that would be difficult to access. Rather than fabricate a poor design, you could:

(1) Redesign the board so that the test point is easy to access.

(2) Keep the design, but select packaging that has a removable access cover.

(3) Keep the design, but manage other components so that the test point is easy to access.

6. Select true statements about grid applications and spacing. Place an "X" beside each true statement.

______a. Remember that the grids displayed on a computer screen are there to aid in the positioning of components and traces.

______b. For pc board layout, the preferred grid spacings are 0.100 inch, 0.050 inch, and 0.025 inch.

______c. For placing DIP packages, drafters prefer 0.1 inch spacing, but for placing packages with closer lead spacing, medium grid spacing works best.

7. Solve problems about common layout scales. Circle the number beside the statement that best solves each of the following problems.

a. You have created a pc board layout on a 1X scale and suddenly realize that when you plot it, the drawing will require better accuracy. You should:

(1) Plot it at a 2X scale.

(2) Plot it at a 2X scale if a reduction facility is available.

(3) Plot it at 4X.

b. You have created a pc board layout on a 2X scale and then realize that most of the layout will require high precision artwork. You should:

(1) Plot the drawing at 4X.

(2) Plot the drawing at 3X.

(3) Plot the drawing at 1X, then reproduce only the parts you need at 4X.

Written Test

8. Use a reference to answer questions about guidelines for selecting trace widths. Reference the following chart, and write the correct answer in the blank provided.

MAXIMUM CURRENT-CARRYING CAPACITY FOR TYPICAL CONDUCTOR WIDTHS AND THICKNESSES

CONDUCTOR WIDTH IN INCHES	1/2 OZ FOIL CURRENT (AMPS)	1 OZ FOIL CURRENT (AMPS)	2 OZ FOIL CURRENT (AMPS)
0.005	0.13	0.50	0.70
0.010	0.50	0.80	1.40
0.020	0.70	1.40	2.20
0.030	1.00	1.90	3.00
0.050	1.50	2.50	4.00
0.070	2.00	3.50	5.00
0.100	2.50	4.00	7.00
0.150	3.50	5.50	9.00
0.200	4.00	6.00	11.00

a. Your conductor trace width is required to handle 5.5 amps, and your board is 2 oz. copper foil. The trace you should use is ____________.

b. You have a board with 1 oz. copper foil that will carry 4 amps. The trace you should use is ____________.

9. Complete statements about guidelines for spacing traces. Circle the material that best completes each of the following statements.

a. Space (**signal**) (**power**) traces a minimum of 0.02" apart unless otherwise specified.

b. Space (**signal and ground**) (**power and ground**) traces a minimum of 0.100" apart unless otherwise specified.

c. Keep the air gap between adjacent traces or pads (**0.02"**) (**0.10"**) apart unless otherwise specified.

Written Test

10. Complete statements about guidelines for trace layouts. Circle the material that best completes each of the following statements.

    a. Run traces (**adjacent**) (**parallel**) to the edge of a board where possible.

    b. Run traces on adjacent layers (**parallel**) (**perpendicular**) to each other.

    c. Use (**number schemes**) (**color schemes**) on double-sided boards or on pc boards with multiple layers.

    d. Keep trace lengths as (**close to components**) (**short**) as possible.

    e. Keep nominal spacing between a trace and (**another trace**) (**the edge of a board or any mounting hardware**) somewhere around 0.100″ to 0.250″.

11. Differentiate between types of component terminal holes and their functions. Place a "U" beside the description of an unsupported hole, and a "P" beside the description of a plated hole.

    ______a. These are holes that have been drilled or punched, but have no connections to the components on a pc board

    ______b. These are holes used to connect traces on various layers of a pc board with multiple layers.

12. Use a reference to answer questions about determining minimum terminal/pad size. Reference the following chart and write the correct answer in the space provided.

    a. The pad diameter needed for a AWG 22 wire is __________.

    b. A lead diameter of .0126″ requires a pad of .093″. Will a pad of .087″ be okay? __________. Why? ____.

    c. A standard .111″ pad handles AWG wire sizes __________ through __________.

RECOMMENDED TERMINAL/PAD AREAS FOR PC BOARDS

AWG	LEAD DIAMETER	STD PAD DIAMETER
34-29	.0063″-.0113″	.075″
28-23	.0126″-.0226″	.093″
22-20	.0253″-.0320″	.093″
19-17	.0359″-.0453″	.111″
16-15	.0508″-.0571″	.125″

Written Test

13. Complete statements about grounding methods and their applications. Circle the material that best completes each of the following statements.

    a. Single point grounds are used with series connections commonly used in low-frequency applications with (**analog**) (**digital**) boards.

    b. Single points grounds are also used with parallel connections used for high-frequency (**analog**) (**digital**) boards.

    c. Multipoint grounds are best suited for use on boards with ground planes or (**single**) (**multiple**) layers.

14. Complete statements about busing techniques. Circle the material that best completes each of the following statements.

    a. Keep voltage and ground bus traces as close to (**ICs**) (**edges**) as possible.

    b. Use power bus traces to provide greater component (**performance**) (**density**) without the need for multilayer boards because manufacturing costs increase with the number of layers.

15. Select true statements about shielding considerations. Place an "X" beside each true statement.

    ______a. Review shielding requirements before starting a pc board layout.

    ______b. Minimize the shielding needed for high-frequency pc boards by using short leads and traces.

    ______c. When special considerations such as electromagnetic interference need to be examined, run whatever tests you have to.

    ______d. When electromagnetic interference is suspected, remember that it is almost always external.

16. Select true statements about shielding techniques. Place an "X" beside each true statement.

    ______a. Place components in an orderly fashion.

    ______b. Place small components first.

    ______c. Mount resistors, capacitors, and other axial lead components either perpendicular or parallel to the edge of the board.

Written Test

______d. Arrange components for the greatest accessibility of interconnections.

______e. Route traces so that the minimum number of crossovers are required, and remember that an excessive number of crossovers adds greatly to manufacturing expense.

17. Select true statements about peripheral orientation. Place an "X" beside each true statement.

______a. When components must be located at the edge of the board or entirely off the board, place those components first.

______b. When edge connectors are used, place them on the board second, and then place any other components that need to be located at the edge of the board.

18. Solve problems related to laying out a pc board on a CAD system. Circle the number beside the statement that best solves each of the following problems.

a. You have been assigned a pc board layout project and want to get started properly. You start to set the snap to ON, but a supervisor says that's not where you should begin. To solve your problem, you should:

(1) Review your software documentation.

(2) Set the grid value appropriate to draw the board outline from the pc board design.

(3) Pick the proper layer first.

b. As you're placing ICs on a pc board drawing, a supervisor points out that one of the ICs has a problem. The first thing you should do to solve the problem is:

(1) Check the BOM to make sure it is the correct IC.

(2) Move the IC around until it fits into the scheme of things better.

(3) Place the IC in near proximity to the components it will be connected to.

***Permission to duplicate this test is granted.**

PC Board Layout
Unit 9

Unit Evaluation Form

Student Name ______________________ Unit Rating __________

Assignment Sheet 1—Print Available Symbols From a CAD System PC Board Library and Create New Symbols For Common Components Rating ______

Comments: ______________________

____

Assignment Sheet 2—Construct a Layout For a PC Board and Plot the Finished Artwork Rating ______

Comments: ______________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

***Permission to duplicate this form is granted.**

PC Board Layout
Unit 9

Information Sheet

1. **Terms and definitions**

   a. **Block diagram** — A diagram that shows groups of components in a general relationship

   b. **BOM (Bill of Materials)** — An itemized list of parts included with an assembly drawing

   c. **Checkplot** — A low resolution plot of a pc board used to save time plotting, but not good for final artwork

   d. **Computer system** — A computer with keyboard, monitor display, a hard or floppy disk for data storage, a device for printing or plotting information, and an operating system and software designed to execute input from an operator

   e. **Conductor** — A medium that passes electrical inputs from one point to another

   f. **Drafting software** — Computer programs designed especially for developing schematics, ladder diagrams, master patterns, marking drawings, and assembly drawings for use in the electronic industry

   g. **Edge connector** — Connector made on the edge of a pc board

   h. **Electromagnetic interference** — Interference caused by magnetism created by current flow in a conductor

   i. **Grid** — The pattern of dots displayed on a computer screen so that a drafter can relate the pattern size and use it as the equivalent of a scale

   j. **Layers** — The single layers of a pc board

   k. **Multilayer board** — A pc board with more than one layer of foil

   l. **Pen plotter** — An output device used to print a precision copy of a drawing created on a CAD system

   m. **Schematic diagram** — A wiring diagram showing all components of an electrical circuit and how they are connected, but the diagram does not show true size, shape, or placement

   n. **Snap** — A command that causes the curser on a CAD system to snap to the nearest grid point

Information Sheet

o. **Test point** — The point on a pc board where a special connector is placed so that a test instrument can be easily connected

p. **Thermal sensitivity** — The amount of degradation in component performance when the component is subjected to temperature change

q. **Trace width** — The width of a conductor that interconnects components on a PC Board

2. **PC Board layout requirements and their functions**

   a. **Schematic/logic diagrams** — Used to determine component connections

   b. **Block diagram** — Used to determine which components should be grouped together

   c. **BOM** — Used to identify each component

   d. **Specifications/mechanicals** — Used to determine other pc board requirements such as clearances, tooling holes, keep-out areas, and physical board size

3. **Component information required for PC Board layout**

   a. Determine the size of all components.

   b. Determine the lead pattern and lead sizes for each component.

   c. Determine the minimum spacing between components.

   d. Determine special mounting data such as heat sink placement.

   e. Determine required terminal area sizes.

   f. Review all electrical and thermal limitations for each component.

   Example: Thermal characteristics are extremely important because components that generate excessive heat may require a heat sink, and heat-generating components have to remain cool.

Information Sheet

4. **Hardware and software requirements for pc board layout**

   a. The basic hardware requirements is a computer system with a sufficient amount of memory and a high speed operating system.

   b. Another essential hardware requirement is a pen plotter or a laser printer to plot and print completed layouts.

   c. Software means drafting software with capabilities for pc board layout and the required documentation.

5. **Other considerations for CAD pc board layout**

   a. Review the grid system, and test the grid command on the CAD system.

   b. Determine the scale size of the final plot of the artwork, and test the CAD system to make sure the system has the ability to produce the plot.

   c. Determine nominal and minimum conductor widths and spacings, and test the CAD system to make sure it can meet the criteria.

   d. Review the board size and run a test outline on the CAD system to make sure the drawing will fit in the CAD system's available work area.

   Note: Determine board size from your pc board design.

   e. Note the number of layers the pc board will require.

   f. Review the proposed manufacturing process, and lay the pc board out so that it can be easily manufactured.

   g. Place test points so that they are easily accessible.

   h. Handle high voltage distribution and decoupling according to appropriate safety codes or regulations.

   i. Locate heat-generating components away from components that might not function properly if exposed to excessive heat.

   j. Consider all mechanical elements, and pay special attention to pc board mounting and packaging.

Information Sheet

6. Grid applications and spacing

a. Remember that the grids displayed on a computer screen are there to aid in the positioning of components and traces.

b. For pc board layout, the preferred grid spacings are 0.100 inch, 0.050 inch, and 0.025 inch.

c. For placing DIP packages, drafters prefer 0.1 inch spacing, but for placing packages with closer lead spacing, the smaller grid spacing works best.

7. Common layout scales

a. For most pc board layout on a CAD system, use a 1:1 or 1X scale so that your scale of the final artwork will require no change when you plot it.

b. When you want more accuracy, plot at 2:1 or 2X, if a reduction facility is available.

c. When you require high precision artwork, or when tolerances between component leads are extremely close, plot at 4:1 or 4X.

8. Selecting trace widths

a. The relationship of foil thickness and current determine what size a trace width should be, and the rule is that higher amperages require wider conductors.

b. Never exceed the maximum current-carrying capacity of a conductor.

MAXIMUM CURRENT-CARRYING CAPACITY FOR TYPICAL CONDUCTOR WIDTHS AND THICKNESSES

CONDUCTOR WIDTH IN INCHES	1/2 OZ FOIL CURRENT (AMPS)	1 OZ FOIL CURRENT (AMPS)	2 OZ FOIL CURRENT (AMPS)
0.005	0.13	0.50	0.70
0.010	0.50	0.80	1.40
0.020	0.70	1.40	2.20
0.030	1.00	1.90	3.00
0.050	1.50	2.50	4.00
0.070	2.00	3.50	5.00
0.100	2.50	4.00	7.00
0.150	3.50	5.50	9.00
0.200	4.00	6.00	11.00

Information Sheet

CAD Alert: Use the trace widths the preceding table when you do layout on a CAD system. If you want to plot at a 2X scale, the CAD system will automatically double the trace widths.

Example A: Your conductor trade width is required to handle 3.5 amps, and your board is 1 oz. copper foil. What trace width should you use?

Answer: The conductor width needs to be 0.70″.

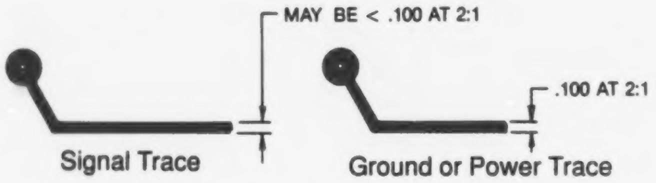
Example B: Your conductor trace is required to handle 20 mA of current, the foil is 1 oz. copper, and the trace width is 0.10″. Is the trace width adequate to handle the current?

Answer: Yes. A trace width of .200″ has a current capacity of 4 amps, and since only 20 mA is required, the trace can easily handle the load.

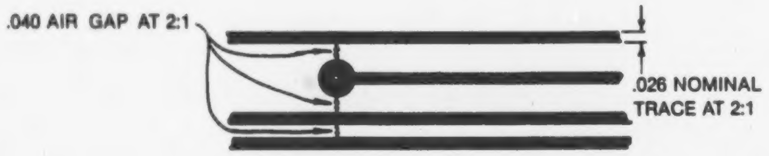
9. Guidelines for spacing traces

a. Space signal traces a minimum of 0.02″ apart unless otherwise specified.

b. Space power and ground traces a minimum of 0.100″ apart unless otherwise specified.



c. Keep the air gap between adjacent traces or pads 0.02″ apart unless otherwise specified.



Note: Technology is moving toward smaller, more powerful components, and as such components require less and less current, they are less susceptible to interference from other signals or traces placed in close proximity. Some modern hi-tech pc boards have traces spaced only a few thousandths of an inch apart.

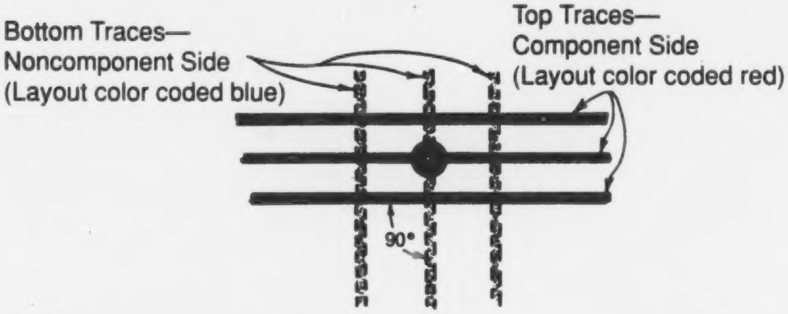
Information Sheet

10. Guidelines for trace layouts

a. Run traces parallel to the edge of a board where possible.

b. Run traces on adjacent layers perpendicular to each other.

c. Use color schemes on double-sided boards or on pc boards with multiple layers.

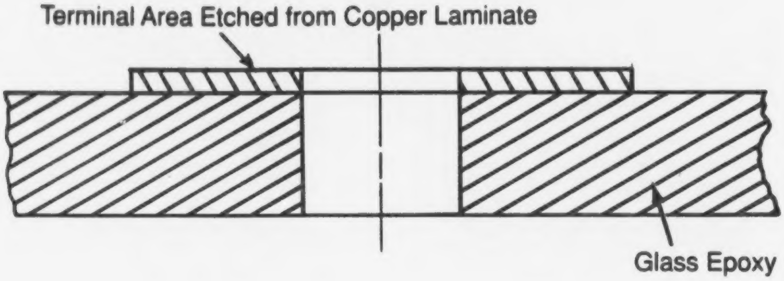

Bottom Traces—
Noncomponent Side
(Layout color coded blue)
Top Traces—
Component Side
(Layout color coded red)
90°

d. Keep trace lengths as short as possible.

e. Keep nominal spacing between a trace and the edge of a board or any mounting hardware somewhere around 0.100″ to 0.250″.

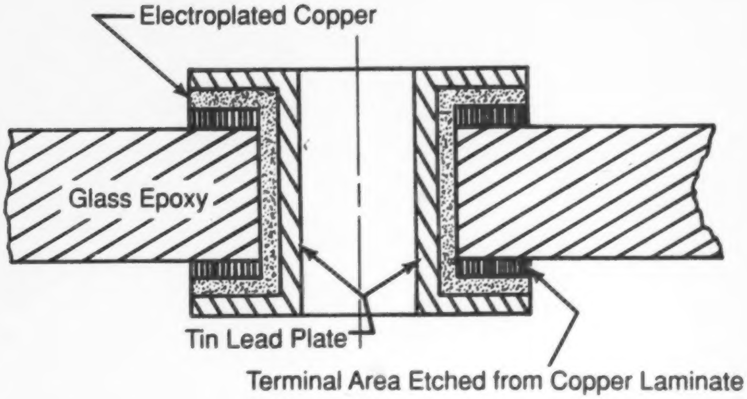
11. Types of component terminal holes and their functions

a. Unsupported holes such as mounting holes that have been drilled or punched, but have no connections to the components on a pc board.


Terminal Area Etched from Copper Laminate
Glass Epoxy

Information Sheet

b. Plated-through holes are holes used to connect traces on various layers of a pc boards with multiple layers.


Electroplated Copper
Glass Epoxy
Tin Lead Plate
Terminal Area Etched from Copper Laminate

12. Determining minimum terminal/pad size

a. Determine pad size in relation to wire size or component lead diameter.

b. Pads that exceed the minimum are acceptable, but never design a pad that is below the specified minimum.

RECOMMENDED TERMINAL/PAD AREAS FOR PC BOARDS

AWG	LEAD DIAMETER	STD PAD DIAMETER
34-29	.0063″-.0113″	.075″
28-23	.0126″-.0226″	.093″
22-20	.0253″-.0320″	.093″
19-17	.0359″-.0453″	.111″
16-15	.0508″-.0571″	.125″

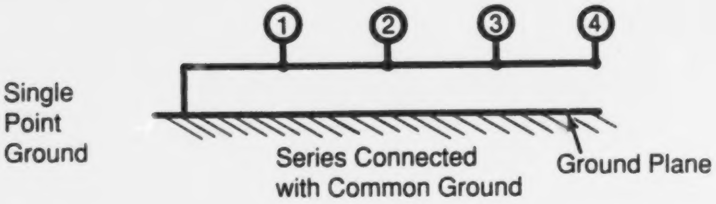
Example: Determine the pad diameter needed for AWG 22 wire.

Answer: A larger pad would be acceptable, but .093″ is the minimum.

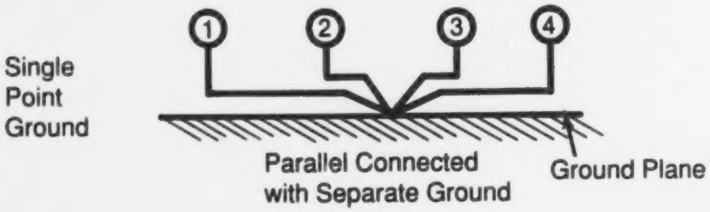
Information Sheet

13. Grounding methods and their applications

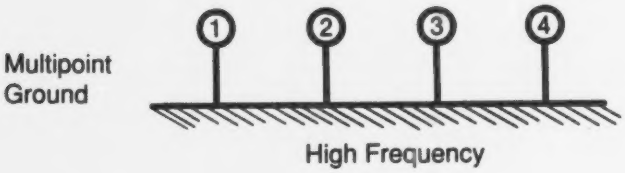
a. Single point grounds are used with series connections commonly used in low-frequency applications with digital boards.


①
②
③
④
Single Point Ground
Series Connected with Common Ground
Ground Plane

b. Single points grounds are also used with parallel connections used for high-frequency analog boards.


①
②
③
④
Single Point Ground
Parallel Connected with Separate Ground
Ground Plane

c. Multipoint grounds are best suited for use on boards with ground planes or multiple layers.


①
②
③
④
Multipoint Ground
High Frequency

14. Busing techniques

a. Keep voltage and ground bus traces as close to ICs as possible.

b. Use power bus traces to provide greater component density without the need for multilayer boards because manufacturing costs increase with the number of layers.

Information Sheet

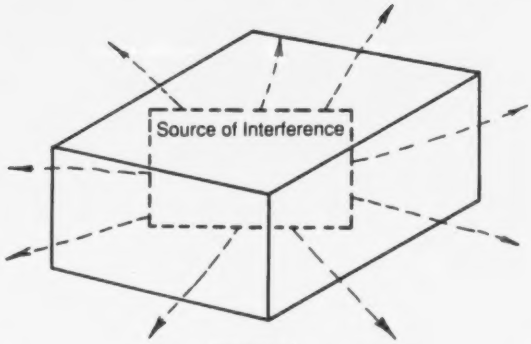
15. General shielding considerations

a. Review shielding requirements before starting a pc board layout.

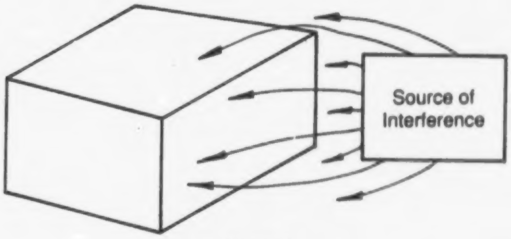
b. Minimize the shielding needed for high-frequency pc boards by using short leads and traces.

c. When special considerations such as electromagnetic interference need to be examined, consult with the Project Engineer.

d. When electromagnetic interference is suspected, remember that it may be external or internal.



Internal
(Example: RF Coil Transformer)



External
(Example: Power Supply Fluorescent Lights)

16. Shielding techniques

a. Place components in an orderly fashion.

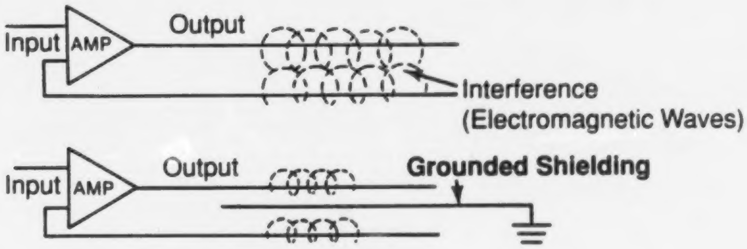
b. Place ICs and other large components first.

c. Mount resistors, capacitors, and other axial lead components either perpendicular or parallel to the edge of the board.

d. Arrange components for the greatest accessibility of interconnections.

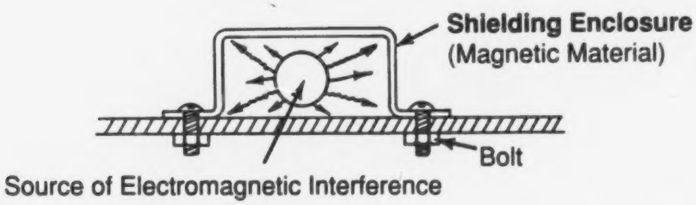
e. Route traces so that the minimum number of crossovers are required, and remember that an excessive number of crossovers usually indicates a need for a multilayered board.

f. Use ground shielding to help control internal electromagnetic waves.


Input
AMP
Output
Interference
(Electromagnetic Waves)
Input
AMP
Output
Grounded Shielding

Preliminary Sketch

g. Use a shielding enclosure to help control electromagnetic interference.


Shielding Enclosure
(Magnetic Material)
Bolt
Source of Electromagnetic Interference

17. Peripheral orientation techniques

a. When components must be located at the edge of the board or entirely off the board, place those components first.

b. When edge connectors are used, place them on the board first, and then place any other components that need to be located at the edge of the board.

Information Sheet

18. Steps in laying out a PC Board on a CAD system

CAD Alert: Carefully read the manual for your CAD system, and the documentation for the software you are using. Familiarize yourself with basic commands, and learn to use them with skill. The process is a real confidence builder.

a. Set the grid to a value appropriate to draw the board outline as presented in the pc board design.

b. Set the snap to ON; this causes all components, traces, and other elements to "snap" to the nearest grid dot.

c. Set the current layer to the layer that you want to place the layout on, and for a single-sided pc board, this is usually layer 3.

d. Set the trace width to the width in thousandths of an inch to the value needed to draw the board outline

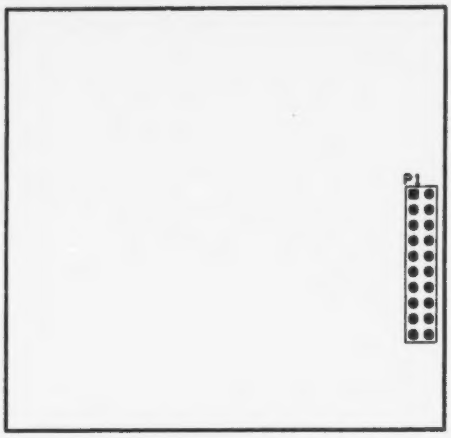
e. Use the trace command to draw the board outline.

Note: You may have to substitute the line command if you're using general drafting software instead of specific pc board layout software.

Information Sheet

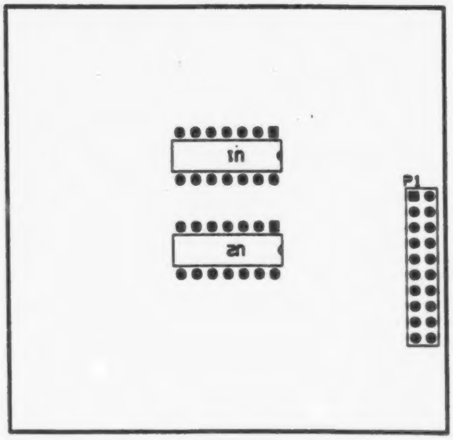
f. Place edge connectors and all components that must be placed on the edge of the board.

CAD Alert: Consult the manual for your CAD system, and use symbols from the pc board library when possible.



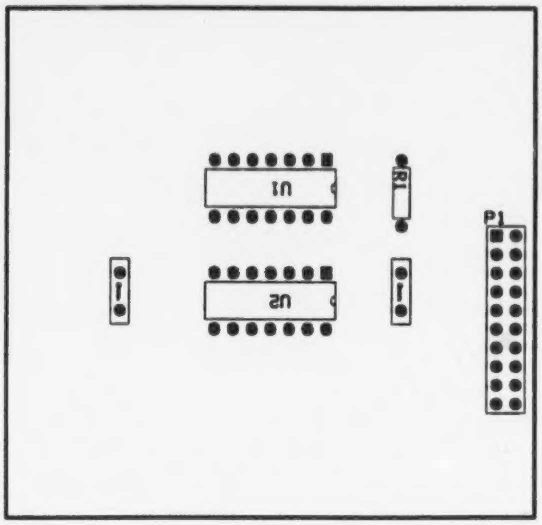
g. Place ICs and other large components on the board in near proximity to the components they will be connected to.

CAD Alert: Remember to check the pc board library for symbols to save you drawing time.

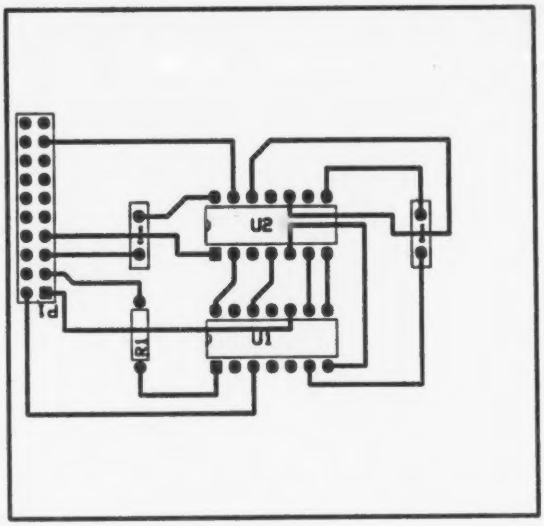


Information Sheet

h. Place resistors, capacitors, and other axial lead components near the components that they will be connected to.



i. Run traces to connect all components as indicated in the schematic.



Information Sheet

j. Plot a checkplot of the board layout.

k. Review the checkplot, and check all connections for accuracy.

l. Print a final plot of the board artwork.

Note: If the fabrication facility has a reduction capability, plot the artwork at 2X.

PC Board Layout
Unit 9

Assignment Sheet 1—Print Available Symbols From a CAD System PC Board Library and Create New Symbols for Common Components

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
Symbols properly plotted and saved	______
2″ by 2″ board outline is to specifications	______
Board outline with pad plotted at 2X scale	______

Directions: Review the documentation for the CAD system you will use, and determine the names of all libraries with symbols specifically for pc board layout. Review the list that follows and plot all symbols that you find in the CAD library.

Note: If you cannot access a CAD system or appropriate software, use appropriate PC Board templates to draw the following items on vellum.

Problem A:

1. 1/4 watt resistor
2. 1/2 watt resistor
3. 100 WVDC ceramic disc
4. TO3 case transistor
5. IC 7404 (DIP 14)
6. IC PGA 84
7. SIP 8
8. 60-pin standard header connector with 0.1″ centers and two rows of pins (HDR60)
9. 20-pin PCC (PCC18)

Assignment Sheet 1

Draw any symbols not available in the library and save them for future use. Plot your new symbols and save them for future reference.

CAD Alert: This is a good opportunity to learn how easy it is to modify and replot board outlines on a CAD system. Even after several changes, your work will look neat because there are never signs of erasures.

Problem B:

1. Create a 2″ × 2″ board outline with a .040″ width.
2. Plot a 2X plot of the board outline.
3. Use the PAD command to place a pad in the board outline, and then plot the board outline at a 2X scale.

PC Board Layout
Unit 9

Assignment Sheet 2—Construct a Layout for a PC Board and Plot the Finished Artwork

Name ______________________ Overall Rating ______________

Evaluation criteria	**Rating**
Board size properly determined	______
Mounting data researched for each component	______
Layout properly drawn and plotted on 2X final artwork	______

Project Information:

All resistors are 1/4 watt
All capacitors are 35 volt WVDC tantalum
Conductor (TRACE) widths should be .020″ minimum

Directions: Consult the schematic on the following page to complete the procedure outlined. If you do not have a CAD system and software available, complete the assignment with appropriate PC Board layout templates and draw the layout at a 2X scale.

Procedure:

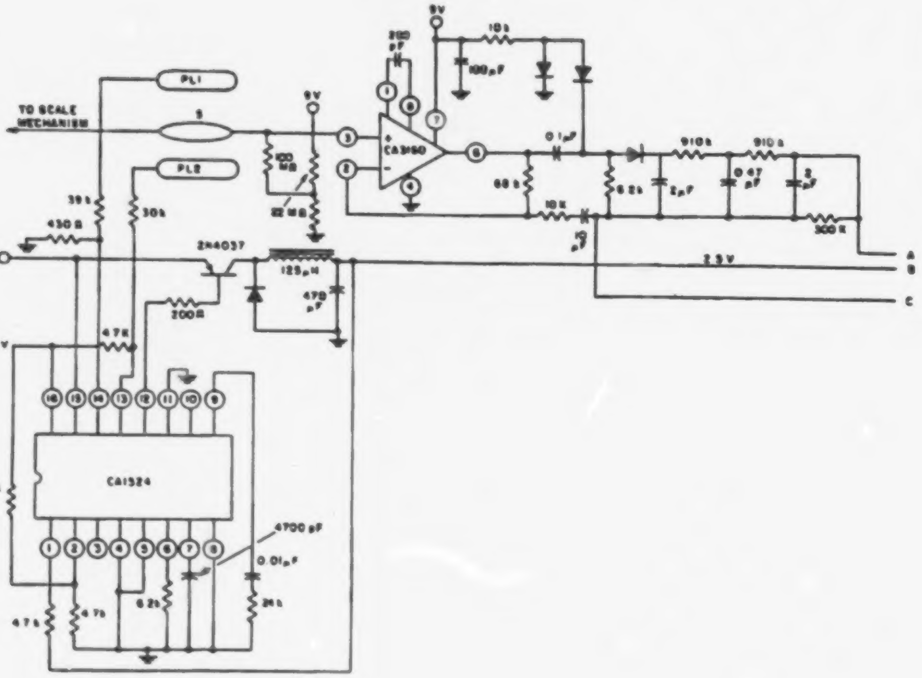
1. Use the schematic on the next page or one selected by your instructor.
2. Consult the PC Board design to determine the board size.
3. Use a manufacturer's catalog or the PC Board library on a CAD system to determine the mounting data for each component.
4. Draw the layout.

   CAD Alert: Remember to draw the entire layout in 1X. You have the option of selecting a 2X or 4X scale when you plot the finished artwork.

5. Plot finished artwork of the layout at 2X.

Assignment Sheet 2

SCHEMATIC DIAGRAM OF DIGITAL READOUT SCALE


9V
200 pF
10k
100 μF
PL1
TO SCALE MECHANISM
S
9V
CA3160
0.1 μF
910k
910k
100 MΩ
PL2
68k
6.2k
2 μF
0.47 μF
2 μF
39k
30k
22 MΩ
10K
10 μF
300K
430Ω
9V
2N4037
125 μH
2.5V
A
B
C
470 pF
200Ω
4.7K
5V
16
15
14
13
12
11
10
9
CA1324
4.7K
1
2
3
4
5
6
7
8
4700 pF
0.01 μF
4.7k
4.7k
6.2k
24k

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PC Board Fabrication
Unit 10

Objective Sheet

Unit Objective

After completing this unit, the student should be able to prepare artwork for pc board fabrication and evaluate a commercial pc board fabrication process. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to pc board fabrication with their meanings.
2. Select true statements about preliminary steps for pc board fabrication.
3. Solve problems about preparing artwork.
4. Select true statements about the pc board photographic process.
5. Solve problems about steps in pc board etching.
6. Solve problems about pc board final fabrication.
7. Prepare artwork for pc board fabrication. (Assignment Sheet 1)
8. Evaluate a commercial pc board fabrication process. (Assignment Sheet 2)

PC Board Fabrication
Unit 10

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparencies as needed if you add instructional items to this unit.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of the Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Because pc fabrication involves etching, you may be working with etchant that requires special attention in a lab. Discuss safety procedures for handling etchant with your students, and have Material Safety Data Sheets available as needed. Especially stress the need for safety goggles, gloves, and safety aprons when working with etchant. Skill areas: **Learning skills, learning to learn.**

2. Find a local or area industry that uses the photographic/etching processes in making pc boards. Invite an engineer or designer from the firm to talk to the class about the processes they use, and have the speaker demonstrate some products and their uses. Skill areas: **Foundation skills, listening.**

3. Arrange for students to visit the industry reference in item 2 above. Assign students to different teams to make notes as they monitor products and processes. Then, have individual group members talk to the class about what they saw. Skill areas: **Group effectiveness skills, teamwork.**

4. Read through Assignment Sheets 1 and 2 carefully. If you do not have dark room facilities for preparing artwork, you may want to examine an alternative process such as the Easy Image™ presensitized pc board process presented in Teacher Supplement 1. Radio Shack also has a PC Board Kit 276-1576 that contains everything needed to produce a pc board.

5. If you do have dark room facilities, you may want to order supplies in quantity from Kepro.

> **Caution: Ferric chloride used in pc board process kits requires special care. Students working with the substance should wear goggles, rubber gloves, and even aprons. Work areas need to be well ventilated.**

Resources Used in Developing This Unit

1. Coombs, Clyde F. Jr. *Printed Circuits Handbook*, 3rd ed. Need place...need publisher, 1988.

2. Coombs, Clyde F. *Printed Circuits, Vol. 1: Engineering and Fundamentals.* NY: McGraw-Hill, 1990.

Suggested Activities

3. Coombs, Clyde F. *Printed Circuits, Vol. 2: Fabrication.* NY: McGraw-Hill, 1991.
4. Ginberg, Gerald. *Printed Circuits Design.* NY: McGraw-Hill, 1991.
5. Byers, T. J. *Printed Circuit Board Design with Computers.* NY: McGraw-Hill, 1991.
6. Villanucci, Robert S, et al. *Electronic Techniques Shop Practices and Construction.* Englewood Cliffs, NJ: Prentice-Hall Inc., a Division of Simon and Schuster, 1993.

Suggested Supplemental Resources

The *IPC-S-100 Standards and Specifications Manual* is a large, four-volume set of materials vital to designing and packaging electronic circuits. The many items in the set may be ordered separately for instructors interested in a particular area. For information about the *IPC-S-100 Standards and Specifications Manual*, order the latest IPC catalog. For ordering information, call 708-677-2850, FAX 708-677-9570 or write to:

IPC
Attn: Order Department
7380 N. Lincoln Avenue
Lincolnwood, IL 60646-1705

Other selections in Clyde F. Coombs' printed circuit board series published by McGraw-Hill in 1990, include: *Printed Circuits, Vol. 3: Soldering, Printed Circuits, Vol. 4: Assembly and Testing*, and *Printed Circuits, Vol. 5: Multilayer and Flexible Circuits*. These texts are generally available at public or university libraries.

PC Board Fabrication
Unit 10

Answers to Assignment Sheets

Assignment Sheet 1

Evaluate according to criteria written in the assignment sheet.

Assignment Sheet 2

Evaluate according to criteria written in the assignment sheet.

PC Board Fabrication
Unit 10

Answers to Written Test

1.

a.	3	d.	10	g.	1	j.	4
b.	7	e.	12	h.	8	k.	4
c.	9	f.	5	i.	11	l.	6

2. a, c, d

3. a. (2)
   b. (3)

4. a, d, e, f, g

5. a. (2)
   b. (3)

6. a. (1)
   b. (3)

PC Board Fabrication
Unit 10

Written Test

Name ______________________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. Chemical used to process film to make a negative

______b. A frame used to hold film during processing

______c. A machine used to project light of a certain size through a negative

______d. A machine used for etching pc boards

______e. A frame used to hold a pc board during the etching process

______f. The process of subjecting a piece of film to light in order to create an image

______g. A solution which stops chemical reactions after a film is developed

______h. A piece of film that has been exposed and developed

______i. A pc board with film laminated to its foil side

______j. A machine used to cut or smooth the edges of pc boards

______k. A machine used to cut pc boards

______l. A solution used to stop the action of a developer by washing developer from a film before it is placed in a fixer

1. Fixer
2. Shear
3. Developer
4. Router
5. Expose
6. Stop bath
7. Developing frame
8. Negative
9. Enlarger
10. Etcher
11. Pre-sensitized pc board
12. Etching frame

Written Test

2. Select true statements about preliminary steps for pc board fabrication. Place an "X" beside each true statement.

   ______a. Obtain a copy of the 2X artwork from the pc layout, and be sure the copy is clean and has no smudges or wrinkles.

   ______b. Examine the artwork for proper drafting terms.

   ______c. Contact the electronic engineer or designer in charge of the project and discuss the critical areas, and determine if any other areas need special attention during fabrication.

   ______d. Study your information carefully, and file the information so it will be available for review during the fabrication process.

3. Solve problems about preparing artwork. Circle the number beside the statement that best solves each of the following problems.

   a. You're heading a team in charge of preparing artwork for a pc board layout. One team member insists the first thing to do is to get the proper kind of film ready, and another team member says you need a negative first. To solve the problem of opinions, you should:

      (1) Note that the second team member is correct and arrange for a camera so the team can bet a high contrast black and white negative to start with.

      (2) Note that the first team member is correct, and have members check for a supply of Kodak Ortho Type II film or equivalent.

      (3) Note that neither team member is totally correct and keep polling the team for other alternatives.

   b. You have just finished preparing artwork for a pc board project and want to make sure the negative will fit. You start to measure the negative, but then realize you will have a problem if you don't:

      (1) Compare the negative with the 2X artwork.

      (2) Look for light spots on the negative.

      (3) Place the negative over the pc board blank to verify that it will fit.

Written Test

4. Select true statements about the pc board photographic process. Place an "X" beside each true statement.

    ______a. Make sure you have everything you will need before entering the dark room where the first three steps of the procedure must be completed.

    ______b. Place a pre-sensitized pc board with the foil side down on the bed of the camera vacuum frame.

    ______c. Set the exposure time to 10 minutes, and expose the pc board to light.

    ______d. Place the pc board in developer and agitate for 3 minutes.

    ______e. Rinse the pc board thoroughly in running water, and smooth out any rough spots with your hand or fingers.

    ______f. Inspect the finished pc board for imperfections in the film; look for very light images.

    ______g. Blot the board dry with a soft paper towel, unless you are going to etch the board immediately.

5. Solve problems about the pc board etching process. Circle the number beside the statements that best solves each of the following problems.

    a. You notice that a coworker has carelessly placed an exposed pc board into an etching frame. You know the problem could easily be that:

        (1) The wrong artwork was probably used.

        (2) Traces or pads may be covered.

        (3) The exposed board may drop out of the etching frame.

    b. You notice that a coworker has taken a pc board from the etcher and seems confused inspecting it. To solve the problem, you should:

        (1) Remind the coworker to check the notes that were taken earlier so the inspection will be in critical areas.

        (2) Remind the coworker to look for copper that has not been removed.

        (3) Immediately rinse the board in clean water.

Written Test

6. Solve problems about pc board final fabrication. Circle the number beside the statement that best solves each of the following problems.

   a. A coworker has been asked to complete final fabrication of a pc board. The coworker knows holes have to be drilled, but there is a problem about where to start. To help your friend, you should:

      (1) Find a chart that shows recommended drill sizes as related to the pad size, AWG wire size, or lead diameter.

      (2) Recommend drilling minimum-size holes because they can always be enlarged.

      (3) Recommend drilling with a standard #55 drill because it produces a medium-size hole.

   b. A friend you work with has just cut a pc board to exact size with a shear, and is admiring how good the board looks. As your friend starts to label the board for production, you should probably:

      (1) Congratulate your friend on a job well done.

      (2) Remind your friend to check the size on a light table.

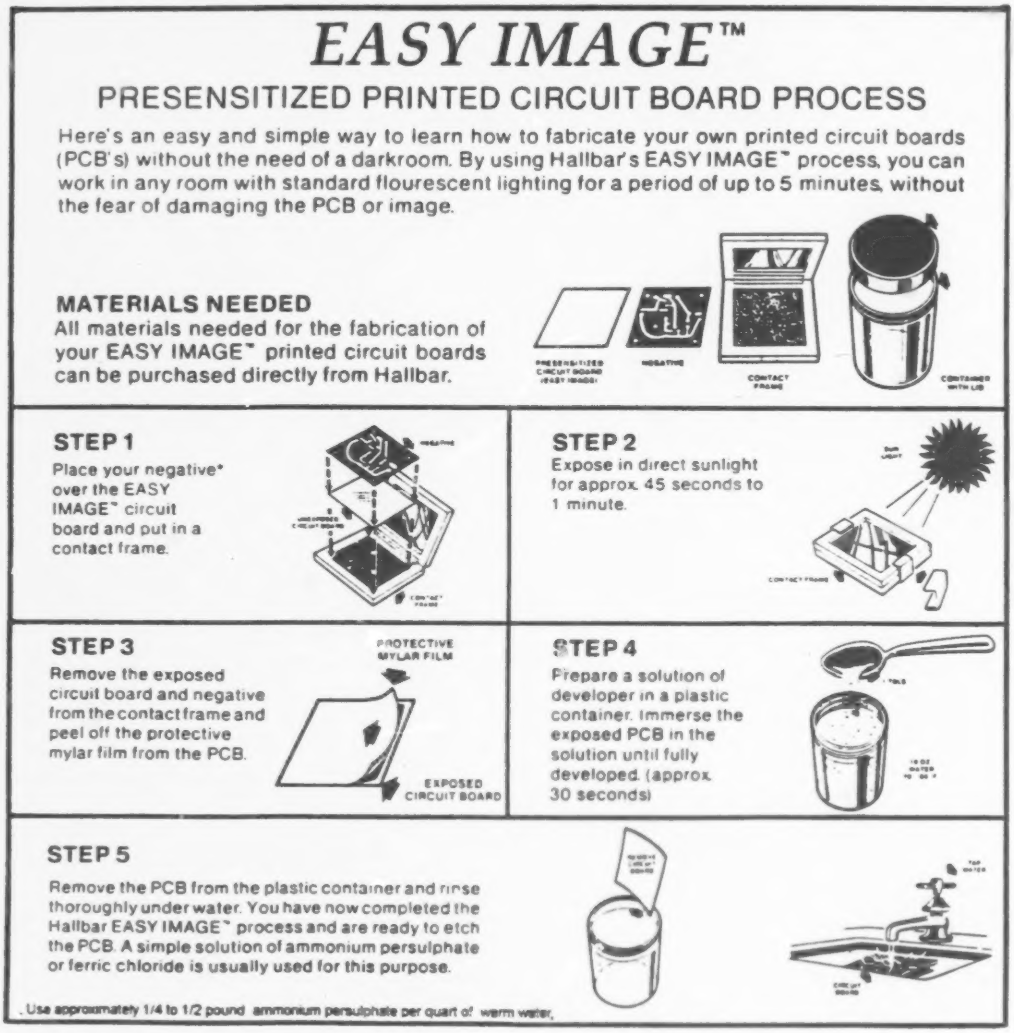
      (3) Remind your friend that the board edges need to be smoothed with sandpaper and burrs left from drilling should be removed.

***Permission to duplicate this test is granted.**

PC Board Fabrication
Unit 10

Teacher Supplement 1—Alternative Process for PC Board Fabrication

The Hallbar Easy Image™ process for pc board fabrication presents an affordable alternative for any drafting program without a darkroom. ©1994, Cal-West Supply, Inc. Reprinted with permission. No product endorsement intended.



EASY IMAGE™

PRESENSITIZED PRINTED CIRCUIT BOARD PROCESS

Here's an easy and simple way to learn how to fabricate your own printed circuit boards (PCB's) without the need of a darkroom. By using Hallbar's EASY IMAGE™ process, you can work in any room with standard flourescent lighting for a period of up to 5 minutes, without the fear of damaging the PCB or image.

MATERIALS NEEDED

All materials needed for the fabrication of your EASY IMAGE™ printed circuit boards can be purchased directly from Hallbar.

STEP 1

Place your negative* over the EASY IMAGE™ circuit board and put in a contact frame.

STEP 2

Expose in direct sunlight for approx. 45 seconds to 1 minute.

STEP 3

Remove the exposed circuit board and negative from the contact frame and peel off the protective mylar film from the PCB.

STEP 4

Prepare a solution of developer in a plastic container. Immerse the exposed PCB in the solution until fully developed. (approx. 30 seconds)

STEP 5

Remove the PCB from the plastic container and rinse thoroughly under water. You have now completed the Hallbar EASY IMAGE™ process and are ready to etch the PCB. A simple solution of ammonium persulphate or ferric chloride is usually used for this purpose.

*Use approximately 1/4 to 1/2 pound ammonium persulphate per quart of warm water.

PRESENSITIZED CIRCUIT BOARD (EASY IMAGE)
NEGATIVE
CONTACT FRAME
CONTAINER WITH LID
NEGATIVE
CONTACT FRAME
SUN LIGHT
CONTACT FRAME
PROTECTIVE MYLAR FILM
EXPOSED CIRCUIT BOARD
TAP WATER
CIRCUIT BOARD

PC Board Fabrication
Unit 10

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Prepare Artwork for PC Board Fabrication Rating _____

Comments: ____

____

Assignment Sheet 2—Evaluate a Commercial PC Board Fabrication Process Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

*Permission to duplicate this form is granted.

PC Board Fabrication
Unit 10

Information Sheet

1. **Terms and definitions**

   a. **Developer** — Chemical used to process film to make a negative

   b. **Developing frame** — A frame used to hold film during processing

   c. **Enlarger** — A machine used to project light of a certain size through a negative

   d. **Etcher** — A machine used for etching pc boards

   e. **Etching frame** — A frame used to hold a pc board during the etching process

   f. **Expose** — The process of subjecting a piece of film to light in order to create an image

   g. **Fixer** — A solution which stops chemical reactions after a film is developed

   h. **Negative** — A piece of film that has been exposed and developed

   i. **Pre-sensitized pc board** — A pc board with film laminated to its foil side

   j. **Router** — A machine used to cut or smooth the edges of pc boards

   k. **Shear** — A machine used to cut pc boards

   l. **Stop bath** — A solution used to stop the action of a developer by washing developer from a film before it is placed in a fixer

2. **Preliminary steps for pc board fabrication**

   a. Obtain a copy of the 2X artwork from the pc layout, and be sure the copy is clean and has no smudges or wrinkles.

   b. Examine the artwork and make a list of all critical areas such as very narrow traces or components placed extremely close to each other.

   c. Contact the electronic engineer or designer in charge of the project and discuss the critical areas, and determine if any other areas need special attention during fabrication.

   d. Study your information carefully, and file the information so it will be available for review during the fabrication process.

Information Sheet

3. Preparing artwork

a. Use a camera to take a photo of the 2X artwork, and develop a high contrast black and white negative from the photo.

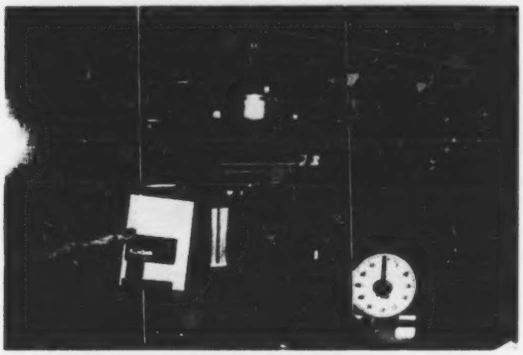
Note: The film process is outlined in the next objective.

b. Place the negative in an enlarger and adjust the scale to 1X.

Note: Complete the procedure in a dark room with a safe light.

c. Focus the negative projection at a point below the enlarger, and then place a sheet of Kodak Ortho Type II film in the same spot where the image was projected.

d. Expose the film for about 3 seconds, although this may vary with conditions.



e. Place the exposed film in a developing frame.

f. Agitate the film in the developer gently for about 45 seconds, but time may vary with chemical and temperature conditions.

g. Watch for film to develop until all areas that should be clear are completely white and all other areas are black.

h. Place the film and holder in a stop bath solution and agitate gently for about 10 seconds.

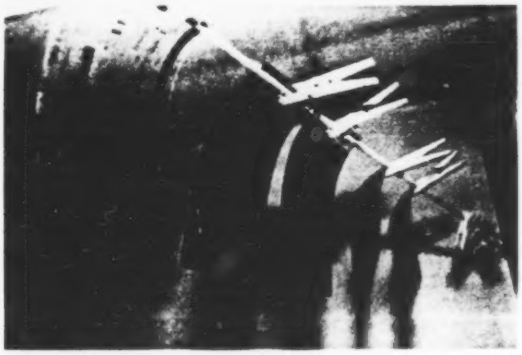
i. Place the film and holder in a fixer solution and agitate gently for about 30 seconds.

Note: Make sure all areas have become transparent before removing the film from the fixer.

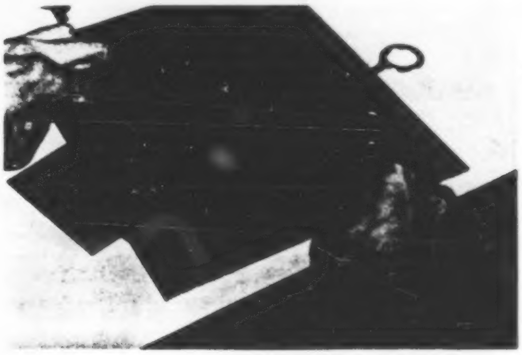
j. Rinse the negative thoroughly in water, and be careful not to touch it.

Information Sheet

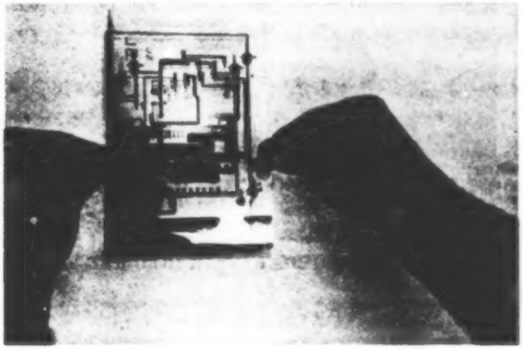
k. Hang the negative on a line to dry, or run it through a film dryer.



l. Check the negative carefully for proper size.



m. Place the negative over a pc blank to verify that the negative will fit.



Information Sheet

4. **The pc board photographic process**

   a. Make sure you have everything you will need before entering the dark room where the first three steps of the procedure must be completed.

   b. Place a pre-sensitized pc board with the foil side up on the bed of the camera vacuum frame.

   c. Set the exposure time to 3 minutes, and expose the pc board to light.

   Note: Exposure time will vary with film type and light intensity.

   d. Place the pc board in developer and agitate for 3 minutes.

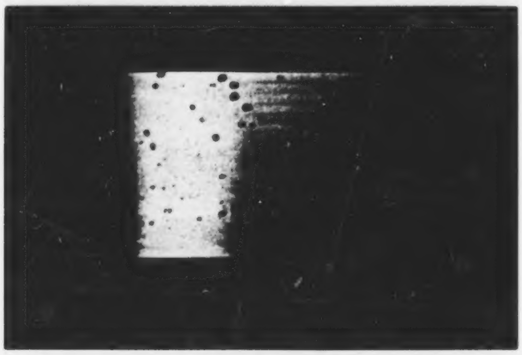
   Note: Do not expose the board to light until it is totally developed.

Information Sheet

e. Rinse the pc board thoroughly in running water, but do not touch or rub the board with your hands or the film will be damaged.

f. Inspect the finished pc board for imperfections in the film; look for very light images.

Note: Do not touch the image on the board.



g. Blot the board dry with a soft paper towel, unless you are going to etch the board immediately.

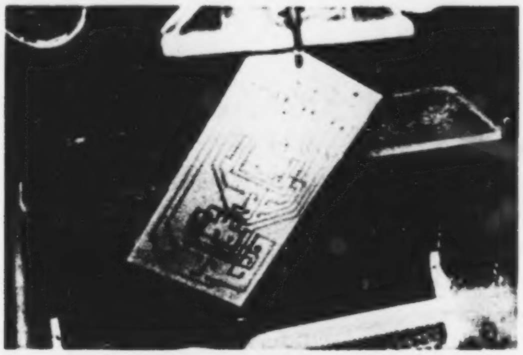
5. **Steps in pc board etching**

a. Put on safety goggles and other safety equipment as directed by your instructor; do not let your hands or exposed skin areas come in contact with etchant.

Information Sheet

b. Place the pc board with the developed image onto the etching frame or in the etcher tray, and be careful not to cover any traces or pads.

c. Start the etcher and watch as the copper is removed from areas not covered by the film.



d. Remove the pc board from the etcher after all copper is removed, and immediately rinse the board in clean water.

Information Sheet

e. Inspect the etched pc board for broken traces or traces or pads that are smudged together.

Note: Now is a good time to also examine all critical areas that you noted when you talked with the engineer or designer.

6. PC board final fabrication

a. Find the proper drill size for holes that have to be drilled in the pc board.

Recommended Drill Sizes for PC Boards

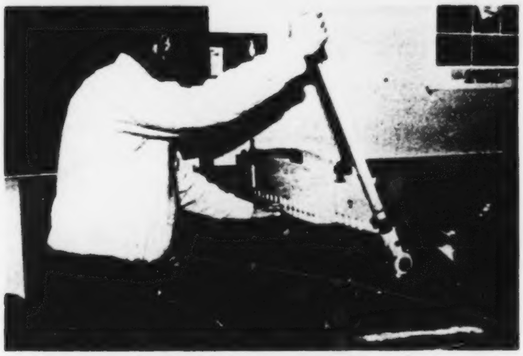
Drill Size	Pad Size	AWG Wire Size	Lead Diameter
#79	.075″	34-29	.0063″-.0113″
#71	.093″	28-23	.0126″-.0226″
#64	.093″	22-20	.0253″-.0320″
#55	.111″	19-17	.0359″-.0453″
#1/16″	.125″	16-15	.0508″-.0571″

Example: The drill size for AWG 18 wire is #55.

Information Sheet

b. Drill the proper size holes in the pc board.

c. Use a shear to cut the pc board to the exact size.



d. Smooth the edges of the pc board with sandpaper or a router.

e. Deburr any burrs left from the drilling process by sanding with fine grain sandpaper.

PC Board Fabrication
Unit 10

Assignment Sheet 1—Prepare Artwork for PC Board Fabrication

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Camera use	______
Film selection and application	______
Development procedure	______

Directions: Your instructor will provide you with 2X artwork to use for starting this assignment. Your instructor may direct you to work with another student or with two other students to complete your artwork. Follow the procedures outline in the information sheet of this unit. If dark room facilities are not available, your instructor may direct you to an alternate assignment.

PC Board Fabrication
Unit 10

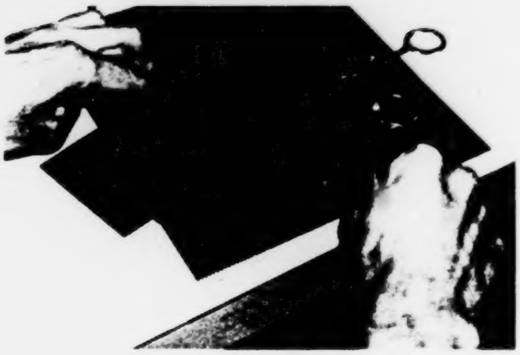
Assignment Sheet 2—Evaluate a Commercial PC Board Fabrication Process

Name ____________________ Overall Rating __________

Evaluation criteria	**Rating**
Process evaluation	______
Product evaluation	______
Safety evaluation	______

Directions: Your instructor has arranged for the class to visit a commercial pc board fabrication facility. Work in teams of three or four to complete an evaluation of the facility. Note the physical layout of the facility and note what personnel at work stations or process stations are doing to help produce a quality product. Make notes of safety standards you observe in your visit. Use the following set of questions as guidelines for a group report, and assign every member of the group an area to report about.

1. Does the facility have an artwork reduction capability?
2. What is the largest size artwork the facility can photograph?
3. What type of film does the facility use to make a negative?
4. Does the facility have the capability to produce double-sided boards?
5. What chemical does the facility use as an etchant?
6. What safety measures did you note in the facility?
7. Is there a notice in the facility that MSDSs are on file or available for personnel to inspect?
8. Who does the pc board drafting for the facility, inplant or imported?
9. Who buys or uses the product produced at the facility?
10. On a scale of 1 to 10, how would you rate the working environment in the facility?



Production Packages
Unit 11

Objective Sheet

Unit Objective

After completing this unit, the student should be able to complete an assembly drawing, complete a bill of materials, and complete an assembly drawing using an intermediary photocopy method. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to production packages with their correct definitions.
2. Match production package components with their functions.
3. Complete statements about guidelines for making an assembly drawing.
4. Select true statements about the CAD system method for preparing assembly drawings.
5. Select true statements about the halftone method for preparing assembly drawings.
6. Complete statements about the outline artwork method for preparing assembly drawings.
7. Complete statements about the component layout method for preparing assembly drawings.
8. Complete statements about the component/master copy method for preparing assembly drawings.
9. Select true statements about the overlay method for preparing assembly drawings.

Objective Sheet

10. Select true statements about the photodrawing method for preparing assembly drawings.
11. Complete statements about notes for assembly drawings.
12. Complete statements about information on a bill of materials.
13. Identify machine screw heads used for mounting hardware.
14. Identify machine screw drive configurations used for mounting hardware.
15. Identify nuts and fasteners used for mounting hardware.
16. Identify washers used for mounting hardware.
17. Identify other devices used for mounting hardware.
18. Complete an assembly drawing. (Assignment Sheet 1)
19. Complete a bill of materials for an assembly drawing. (Assignment Sheet 2)
20. Complete an assembly drawing using an intermediary and photocopy method. (Assignment Sheet 3)

Production Packages
Unit 11

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparencies from transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Contents of a Production Package (Objectives 1 and 2)
   TM 2—Assembly Drawing (Objective 3)

5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of the Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.

Suggested Activities

13. Give written test.

14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Try to get an assembly drawing from a local or area manufacturer so students can see an assembly drawing of a product they can associate with the drawing. Skill areas: **Learning skills, learning to learn.**

2. Find an area manufacturing firm that will welcome students for an arranged visit. Divide students into teams and have them report on the production procedure the firm uses. Have students give group reports in class. **Group effectiveness skills, teamwork.**

3. If the Public Information Office at your school has a photo lab, ask the PIO director to assist you with some of the procedures that require a darkroom and film.

Resources Used In Developing This Unit

1. McClain, Gerald R. and Neal A. Wilson. *Electronic Drafting.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1983.

2. *Newark Electronics, Catalog 113.* Chicago, IL: Neward Electronics, 1994.

3. Raskhodoff, Nicholas M. *Electronic Drafting and Design,* 5th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., a Division of Simon & Schuster, 1987.

4. Villanucci, Robert S., et al. *Electronic Techniques Shop Practices and Construction,* 4th ed. Englewood Cliffs, NJ: Prentice-Hall, a Division of Simon & Schuster.

Suggested Activities

Suggested Supplemental Resources

1. Coombs, Clyde F. *Printed Circuits, Vol. 2: Fabrication.* NY: McGraw-Hill, 1990.
2. Coombs, Clyde F. *Printed Circuits, Vol. 3: Soldering.* NY: McGraw-Hill, 1990.
3. Coombs, Clyde F. *Printed Circuits, Vol. 4: Assembly & Testing.* NY: McGraw-Hill, 1990.
4. Coombs, Clyde F. *Printed Circuits, Vol. 5: Multilayer & Flexible Circuits.* NY: McGraw-Hill, 1990.

Production Packages
Unit 11

Answers to Assignment Sheets

Assignment Sheets 1, 2, and 3

Evaluate all assignment sheets according to criteria written in each assignment sheet. Drawings will vary depending on hardware and software availabilities, but contents should be standard ones that reflect materials in the Information Sheet.

Production Packages
Unit 11

Answers to Written Test

1. a. 5 f. 8
b. 6 g. 1
c. 2 h. 9
d. 10 i. 7
e. 4 j. 3

2. a. 4 d. 2
b. 1 e. 5
c. 6 f. 3

3. a. Height
b. Precision
c. Schematic diagram
d. Mounting
e. Conductor
f. Polarized
g. During and after
h. Circles
i. All

4. a, b

5. a, b, d

6. a. Spread
b. Spacer
c. Original master pattern
d. Appropriate notes

7. a. Master pattern
b. Notes

8. a. An intermediary copy
b. Intermediary

9. b, c

10. a, b

Answers to Written Test

11. a. Standards
    b. Polarized
    c. Coatings

12. a. Description of
    b. Number
    c. Substitution
    d. Numbers

13. a. Fillister
    b. Round
    c. Flat

14. a. Slotted
    b. Hexagonal
    c. Phillips

15. a. Knurled thumb nuts
    b. Square
    c. Cap nut

16. a. Flat
    b. External lock
    c. Internal lock

17. a. Grommet
    b. Fiber shoulder washer

Production Packages
Unit 11

Written Test

Name ______________________ Date ______________ Score ______

1. Match the terms on the right with the correct definitions.

______a. A drawing which shows the functional position of all parts

______b. A humidity seal that covers a pc board to reduce oxidation

______c. A drawing that indicates what order and size to drill the holes on a pc board

______d. A package or enclosure in which the pc board is mounted after assembly

______e. A washer used to provide insulation of a stud from the metal edge of an access hole

______f. A rubber insulator that fits around a hole in a pc board or enclosure to prevent wires from rubbing together

______g. A reproduction of an original which will be used to make the final copy

______h. A circuit interconnection not etched on a pc board

______i. A test used to determine if a pc board is acceptable

______j. A metal extension used to mount a pc board to a case

1. Intermediate copy
2. Drill plan
3. Stud
4. Fiber shoulder washer
5. Assembly drawing
6. Conformal coating
7. Specifications test
8. Grommet
9. Jumper wire
10. Enclosure

Written Test

2. Match production package components with their functions. Place the number beside the component in the blank beside the description of its function.

   _____a. Provides a master pattern to show how to manufacture a pc board and a solder mask to show how to create a solder mask for a pc board

   _____b. Clearly indicates component orientation and critical dimensions

   _____c. Lists all components and materials required for a complete production package

   _____d. Includes printed wiring board drawing and drill plan

   _____e. Shows how all electronic parts are interconnected

   _____f. Indicates testing procedures for the pc board and the complete assembled pc board and enclosures

   1. Assembly drawing
   2. Master drawing
   3. Test specifications
   4. Artwork
   5. Schematic diagram
   6. Bill of materials

3. Complete statements about guidelines for making an assembly drawing. Circle the material that best completes each of the following statements.

   a. Always make an assembly drawing so it can be viewed from the (**top**) (**component side**); it may be a topographical view or a side view, but must clearly indicate component (**size**) (**height**).

   b. Use a (**precision**) (**1X**) scale and standard symbols for each component.

   c. Use reference designators where they are required, and make the designators agree with the ones on the (**schematic diagram**) (**bill of materials**).

   d. Indicate the (**assembly**) (**mounting**) method for components, solder, threaded fasteners, rivets, glue, or other.

   e. Indicate the jumper wires clearly and include the type and size of (**connection**) (**conductor**) to be used.

Written Test

f. Mark (**polarized**) (**containerized**) components such as transistors, ICs, and diodes to indicate their proper orientation.

g. Include general and specific notes about fabrication testing (**during and after**) (**during**) assembly.

h. Identify all electronic parts with (**circled**) (**reference**) numbers and leaders.

i. Include a bill of materials with (**basic**) (**all**) electronic and nonelectronic elements.

4. Select true statements about the CAD system methou for preparing assembly drawings. Place an "X" beside each true statement.

______a. Select the layer of the drawing that shows the component outlines.

______b. Add the board outline and appropriate notes to the layer.

______c. Plot a copy of the layer using a dot-matrix printer.

5. Select true statements about the halftone method for preparing assembly drawings. Place an "X" beside each true statements.

______a. The halftone method for preparing assembly drawings is an option when a CAD system is not available.

______b. Make a good halftone photograph (screened) print of the component side of the master pattern.

______c. Photographically produce the halftone print on quality photographic material.

______d. Draw in the component outlines and reference designations.

______e. Add notes as needed, but no board outline is needed.

6. Complete statements about the outline artwork method for preparing assembly drawings. Circle the material that best completes each of the following statements.

a. Produce a (**spread**) (**positive**) negative by placing the master pattern negative on top of a transparent film spacer.

b. Place the master pattern and film (**holder**) (**spacer**) on top of a piece of duplicating film, and contact print the spread negative.

Written Test

c. Register the spread negative and (**original master pattern**) (**contact print**) together, and contact print.

d. Add board outline and (**bill of materials**) (**appropriate notes**).

7. Complete statements about the component layout method for preparing assembly drawings. Circle the material that best completes each of the following statements.

   a. Make a reproducible copy of the component marking artwork on an intermediary copy, and note that the (**board outline drawing**) (**master pattern**) is omitted in this method.

   b. Add board outline and appropriate (**notes**) (**symbols**) to the intermediary.

8. Complete statements about the component/master copy method for preparing assembly drawings. Circle the material that best completes each of the following statements.

   a. Make a reproducible copy of the original master pattern artwork on (**an intermediary copy**) (**a sheet of drawing paper**).

   b. Add board outline and appropriate notes to the (**intermediary**) (**master pattern**).

9. Select true statements about the overlay method for preparing assembly drawings. Place an "X" beside each true statement.

   ______a. Place the master pattern and the drafting media side by side.

   ______b. Sketch the component outlines on the drafting media from the master pattern artwork.

   ______c. Add board outline and appropriate notes.

10. Select true statements about the photodrawing method of preparing assembly drawings. Place an "X" beside each true statement.

   ______a. Photograph a completely assembled pc board.

   ______b. Print a halftone of the pc board onto a standard drawing format.

   ______c. Add appropriate notes and board outline to the photodrawing.

Written Test

11. Complete statements about notes for assembly drawings. Circle the material that best completes each of the following statements.

    a. Notes for assembly drawings may include general references to other drawings, or general references to company (**standards**) (**references**) for assembly and soldering.

    b. Specific notes on assembly drawings should include component insertion requirements for transistors and other (**packaged**) (**polarized**) components.

    c. Other specific notes include board identification, and indication of conform, solder mask, or other special (**assemblies**) (**coatings**) required.

12. Complete statements about information on a bill of materials. Circle the material that best completes each of the following statements.

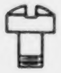
    a. A bill of materials should always include a manufacturer's number and a (**description of**) (**order number for**) the item or component.

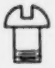
    b. Include reference designation or parts numbers, and the (**number**) (**grade**) of parts required.

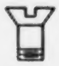
    c. List the assembly name and number, and include notes, remarks, or (**assembly**) (**substitution**) information.

    d. It is a convention to group like components together on a bill of materials, and even components of the same value and type are listed together even though they have different (**suppliers**) (**numbers**).

13. Identify machine screw heads used for mounting hardware. Write the correct name of each of the machine head screws in the following illustrations.



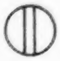


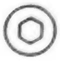


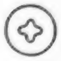
a. ____________ b. ____________ c. ____________

Written Test

14. Identify machine screw drive configurations used for mounting hardware. Write the correct name of each of the machine screw drive configurations in the following illustrations.

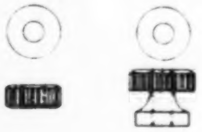


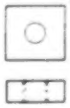


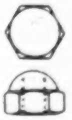


a. ____________ b. ____________ c. ____________

15. Identify nuts and fasteners used for mounting hardware. Write the correct name of each nut or fastener in the following illustrations.

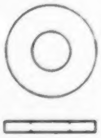


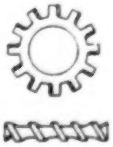


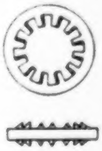


a. ____________ b. ____________ c. ____________

16. Identify washers used for mounting hardware. Write the correct name of each of the washers in the following illustrations.

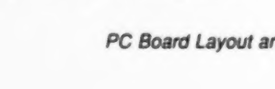


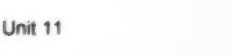




a. ____________ b. ____________ c. ____________

17. Identify other devices used for mounting hardware. Write the correct name of the devices in the following illustrations.





a. ________________________ b. ________________________

***Permission to duplicate this test is granted.**

Production Packages
Unit 11

Unit Evaluation Form

Student Name ________________________ Unit Rating __________

Assignment Sheet 1—Complete an Assembly Drawing Rating ______

Comments: ____

____

Assignment Sheet 2—Complete a Bill of Materials For an Assernbly Drawing Rating ______

Comments: ____

____

Assignment Sheet 3—Complete an Assembly Drawing Using an Intermediary and Photocopy Method Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ________________________ Date __________

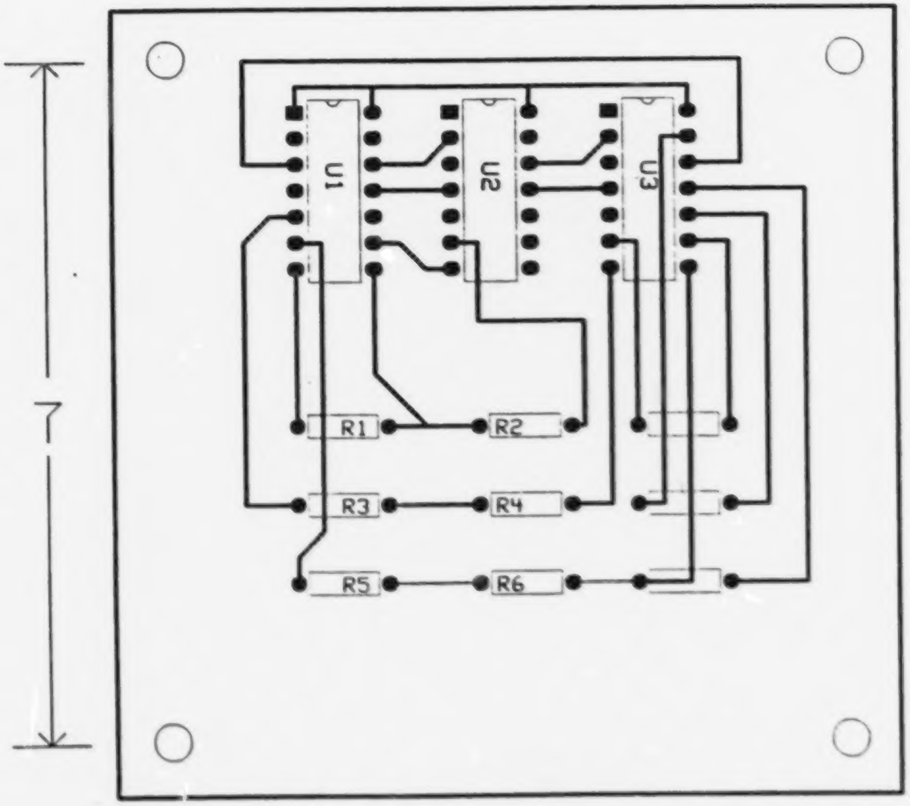
Student Signature ________________________ Date __________

***Permission to duplicate this form is granted.**

Contents of a Production Package

1. Schematic Diagram
2. Artwork
    a. Master Pattern Artwork
    b. Solder Mask
    c. Marking Artwork
3. Master Drawing
    a. Printed Wiring Board Drawing
    b. Drill Plan
4. Assembly Drawing
5. Bill of Materials
6. Test Specifications

Assembly Drawing


U1
U2
U3
R1
R2
R3
R4
R5
R6

Production Packages
Unit 11

Information Sheet

1. **Terms and definitions**

   a. **Assembly drawing** — A drawing which shows the functional position of all parts

   b. **Conformal coating** — A humidity seal that covers a pc board to reduce oxidation

   c. **Drill plan** — A drawing that indicates what order and size to drill the holes on a pc board

   d. **Enclosure** — A package or enclosure in which the pc board is mounted after assembly

   e. **Fiber shoulder washer** — A washer used to provide insulation of a stud from the metal edge of an access hole

   f. **Grommet** — A rubber insulator that fits around a hole in a pc board or enclosure to prevent wires from rubbing together

   g. **Intermediate copy** — A reproduction of an original which will be used to make the final copy

   h. **Jumper wire** — A circuit interconnection not etched on a pc board

   i. **Specifications test** — A test used to determine if a pc board is acceptable

   j. **Stud** — A metal extension used to mount a pc board to a case

2. **Production package components and their functions**

   a. **Artwork** — Provides a master pattern to show how to manufacture a pc board and a solder mask to show how to create a solder mask for a pc board

   Note: If a CAD system is not used, marking artwork may be needed.

   b. **Assembly drawing** — Clearly indicates component orientation and critical dimensions

   c. **Bill of materials** — Lists all components and materials required for a complete production package

   d. **Master drawing** — Includes printed wiring board drawing and drill plan

Information Sheet

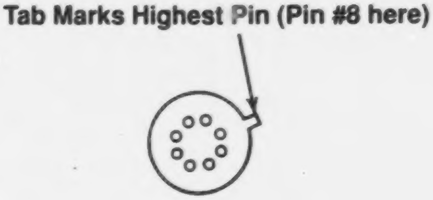
e. **Schematic diagram** — Shows how all electronic parts are interconnected

f. **Test specifications** — Indicates testing procedures for the pc board and the complete assembled pc board and enclosures

3. **Guidelines for making an assembly drawings**

a. Always make an assembly drawing so it can be viewed from the component side; it may be a topographical view or a side view, but must clearly indicate component height.

b. Use a precision scale and standard symbols for each component.

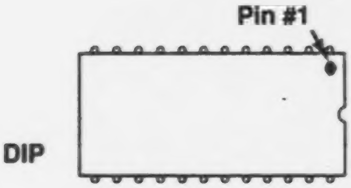


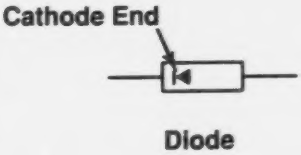
c. Use reference designators where they are required, and make the designators agree with the ones on the schematic diagram.

d. Indicate the mounting method for components, solder, threaded fasteners, rivets, glue, or other.

e. Indicate the jumper wires clearly and include the type and size of conductor to be used.

f. Mark polarized components such as transistors, ICs, and diodes to indicate their proper orientation.





g. Include general and specific notes about fabrication testing during and after assembly.

h. Identify all electronic parts with circled numbers and leaders.

i. Include a bill of materials with all electronic and nonelectronic elements.

Information Sheet

4. The CAD system method for preparing assembly drawings

a. Select the layer of the drawing that shows the component outlines.

b. Add the board outline and appropriate notes to the layer.

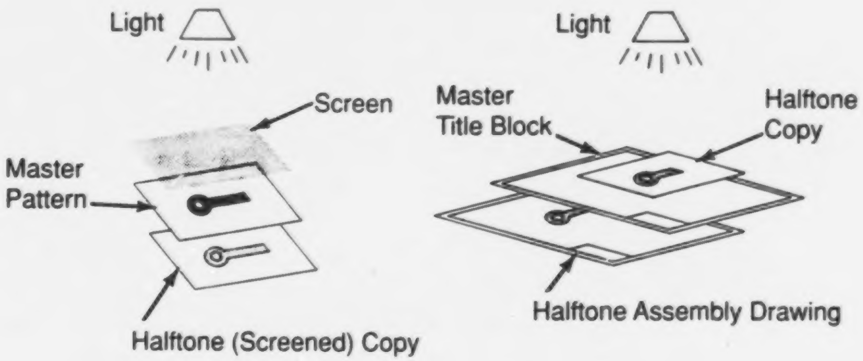
c. Plot a copy of the layer using a pin plotter or a laser printer.

> **CAD Alert:** The CAD system method is efficient because the component outline drawings can be taken from the pc board layout. This increases drawing speed and narrows the probability of errors.

5. The halftone method for preparing assembly drawings

a. The halftone method for preparing assembly drawings is an option when a CAD system is not available.

b. Make a good halftone photograph (screened) print of the component side of the master pattern.


Light
Screen
Master Pattern
Halftone (Screened) Copy
Light
Master Title Block
Halftone Copy
Halftone Assembly Drawing

c. Photographically produce the halftone print on a standard drawing format.

d. Draw in the component outlines and reference designations.

e. Add the board outline and appropriate notes.

6. The outline artwork method for preparing assembly drawings

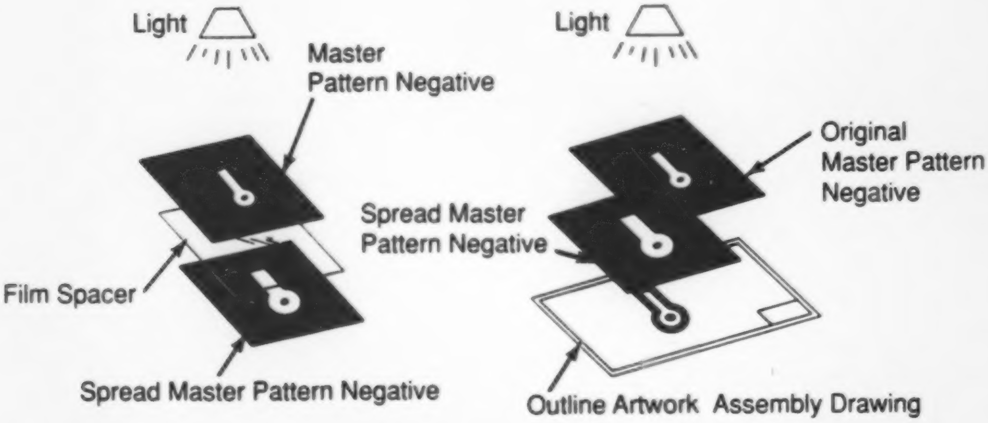
a. Produce a spread negative by placing the master pattern negative on top of a transparent film spacer.

Information Sheet

b. Place the master pattern and film spacer on top of a piece of duplicating film, and contact print the spread negative.

Note: To make wider lines on the spread negative, use a thicker film spacer.

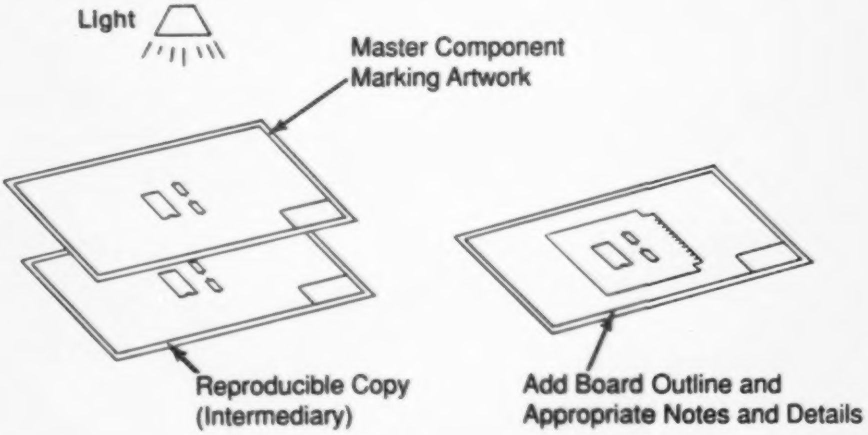
c. Register the spread negative and contact print together, and contact print.


Light
Master Pattern Negative
Film Spacer
Spread Master Pattern Negative
Light
Original Master Pattern Negative
Spread Master Pattern Negative
Outline Artwork
Assembly Drawing

d. Add board outline and appropriate notes.

7. **The component layout method for preparing assembly drawings**

a. Make a reproducible copy of the component marking artwork on an intermediary copy, and note that the master pattern is omitted in this method.

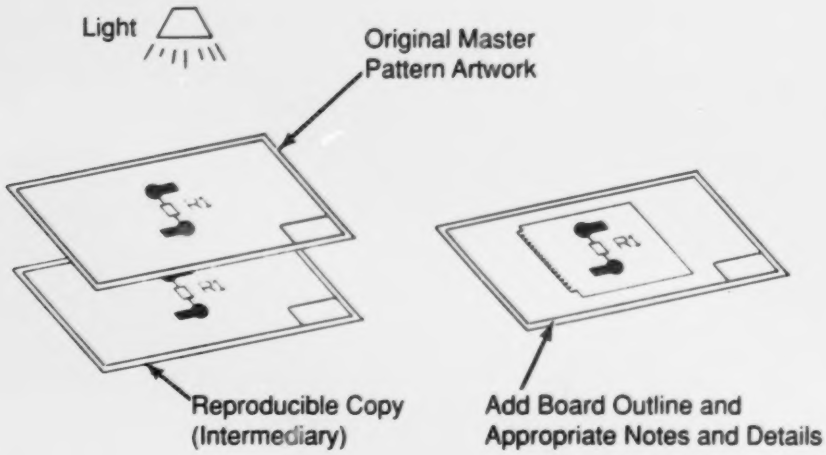

Light
Master Component Marking Artwork
Reproducible Copy (Intermediary)
Add Board Outline and Appropriate Notes and Details

b. Add board outline and appropriate notes to the intermediary.

Information Sheet

8. **The component/master copy method for preparing assembly drawings**

   a. Make a reproducible copy of the original master pattern artwork on an intermediary copy.


Light
Original Master Pattern Artwork
R1
R1
R1
Reproducible Copy (Intermediary)
Add Board Outline and Appropriate Notes and Details

   b. Add board outline and appropriate notes to the intermediary.

9. **The overlay method for preparing assembly drawings**

   a. Place the master pattern artwork under the drafting media.

   b. Use a light table to trace the component outlines on the drafting media from the master pattern artwork.

   c. Add board outline and appropriate notes.

10. **The photodrawing method of preparing assembly drawings**

   a. Photograph a completely assembled pc board.

   b. Print a halftone of the pc board onto a standard drawing format.

   c. Add appropriate notes and dimensions to the photodrawing.

Information Sheet

11. Notes for assembly drawings

a. Notes for assembly drawings may include general references to other drawings, or general references to company standards for assembly and soldering.

Examples: REFERENCE ELECTRICAL SCHEMATIC DIAGRAM XXX

ASSEMBLE AND SOLDER PER XXX.X SPEC

Note: The Xs will, of course, be numbers or letter/number combinations.

b. Specific notes on assembly drawings should include component insertion requirements for transistors and other polarized components.

Example: OBSERVE POLARITY OF CAPACITORS AND DIODES

c. Other specific notes include board identification, and indication of conform, solder mask, or other special coatings required.

Examples: BOARD TO BE CONFORMAL COATED IN ACCORDANCE WITH XXX MIL SPEC TEST POINTS AND ADJUSTABLE COMPONENTS SHALL BE MASKED DURING COATING

USE AUTOMATIC ASSEMBLY FOR THE FOLLOWING COMPONENTS; XXX RESISTORS, XX DIODES

12. Information on a bill of materials

a. A bill of materials should always include a manufacturer's number and a description of the item or component.

b. Include reference designation or parts numbers, and the number of parts required.

c. List the assembly name and number, and include notes, remarks, or substitution information.

Information Sheet

d. It is a convention to group like components together on a bill of materials, and even components of the same value and type are listed together even though they have different numbers.

Bill of Materials

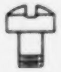
PARTS LIST	BRYTEK, INC.	CONTRACT NO.
TITLE FSK DECODER, PACKAGE, PCB, COMPONENTS		DRAWING NO.

ITEM NO.	QTY	REFERENCE NO.	PART NO.	DESCRIPTION
1	1	U1	LM565	PLL - UNIT
2	1	U2	LM710	COMPARATOR
3	2	R1, R2	600Ω	1/4W 600Ω RESISTOR
4	1	R3	5KΩ	1/4W 5KΩ RESISTOR
5	3	R4, R5, R6	10KΩ	1/4W 10KΩ RESISTOR
6	1	C1	0.1uF	0.1uF CAPACITOR
7	1	C2	0.05uF	0.05uF CAPACITOR
8	1	C3	0.01uF	0.01uF CAPACITOR
9	4	C4-C7	0.02uF	0.02uF CAPACITOR
10	1	H1	H1	WIRING HARNESS
11	1	PCB1	PCB1	PRINTED CIRCUIT BOARD
12	1	SCH1	SCH1	SCHEMATIC DIAGRAM

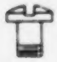
Information Sheet

13. Machine screw heads used for mounting hardware

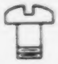
a. Fillister



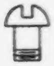
b. Binder



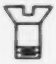
c. Pan



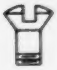
d. Round



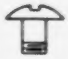
e. Flat



f. Oval



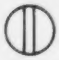
g. Truss



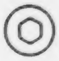
Information Sheet

14. Machine screw drive configurations used for mounting hardware

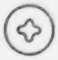
a. Slotted



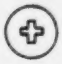
b. Hexagonal (Allen)



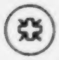
c. Phillips



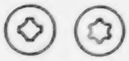
d. Frearson



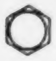
e. Pozidrive



f. Briston

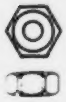


g. Hexagonal (External)

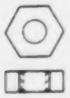


15. Nuts and fasteners used for mounting hardware

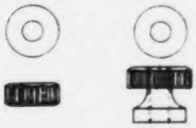
a. Hexagonal



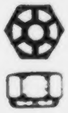
b. Jam



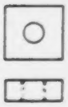
c. Knurled thumb nuts



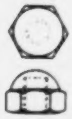
d. Interference stop nut



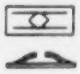
e. Square



f. Cap nut



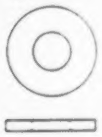
g. Spring stop nut



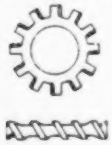
Information Sheet

16. Types of washers used for mounting hardware

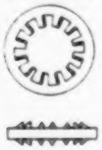
a. Flat



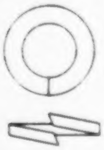
b. External lock



c. Internal lock

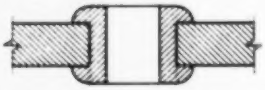


d. Split lock

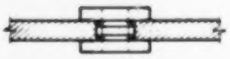


17. Other devices used for mounting hardware

a. Grommet



b. Fiber shoulder washer



Note: There are many other devices for mounting hardware.

Production Packages
Unit 11

Assignment Sheet 1—Complete an Assembly Drawing

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
Component orientation clearly indicated	______
Critical dimensions properly given	______
Polarized components indicated	______
General and specific notes added	______
Space left for bill of materials	______
Drawn to precision scale with standard symbols	______

Directions: Select the master pattern artwork for a single-sided board from Assignment Sheet 1 in Unit 10. Complete an assembly drawing using a CAD system and appropriate software. Refer to Objective 3 in the Information Sheet of this unit for a list of items that should be in an assembly drawing. Allow space for the bill of materials above the title block, but omit the bill of materials at this time.

Production Packages
Unit 11

Assignment Sheet 2—Complete a Bill of Materials For an Assembly Drawing

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
Proper bill of materials form used	_____
Reference designations noted	_____
Part numbers and descriptions included	_____
Quantities and other references included	_____

Directions: Complete a bill of materials for the assembly drawing from Assignment Sheet 1 which you just completed. Be sure to include on your BOM part numbers, component designations, item descriptions, quantities, and manufacturers' numbers.

CAD Alert: If you are using a CAD system with application-specific pc board software, you can automatically extract the bill of materials with a software command. This reduces the chances for human error, and saves valuable time and money.

Production Packages
Unit 11

Assignment Sheet 3—Complete an Assembly Drawing Using An Intermediary and Photocopy Method

Name ______________________ Overall Rating ______________

Evaluation criteria	**Rating**
Master pattern artwork used	______
Bill of materials included	______
Board outline and appropriate notes included	______

Directions: Use the master pattern artwork from Assignment Sheet 1 to complete this assignment. Refer to the Information Sheet if you have questions about materials needed for this assignment, or talk with your instructor if you have questions. Complete your work with a copy of the Bill of Materials which you prepared in Assignment Sheet 2.